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Vibration Isolation of Aircraft Power Plants*

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Introduction

VIBRATION in aircraft structure can almost always be traced to vibratory forces originating from the power plant. These forces are transmitted to the aircraft in two ways: (1) by the action of air forces upon the surfaces of the aircraft in, or adjacent to, the slip stream of the propeller, and (2) by direct transmission of unbalanced forces from the power plant through the engine mounting. The latter has always caused the preponderance of disturbance. Vibratory stresses induced in the engine mounting structure occasionally produce fatigue failures in the associated parts, and always shorten the useful life of the entire aircraft structure. More important, however, are the psychological and physiological effects of continuous vibration and its attendant noise on the passengers and crew. This may very likely be the major source of the rapid fatigue which is so intimately associated with flying. The importance and desirability of drastically reducing vibration can hardly be questioned.

This paper is limited to a consideration of the directly transmitted forces and, further, considers the power plants as rigid bodies attached by flexible means to the aircraft which is also considered as a rigid body of relatively large mass. It is also limited to the case of engines and engine supporting structures having axial symmetry (radial engines), although the methods employed could easily be extended to other cases.

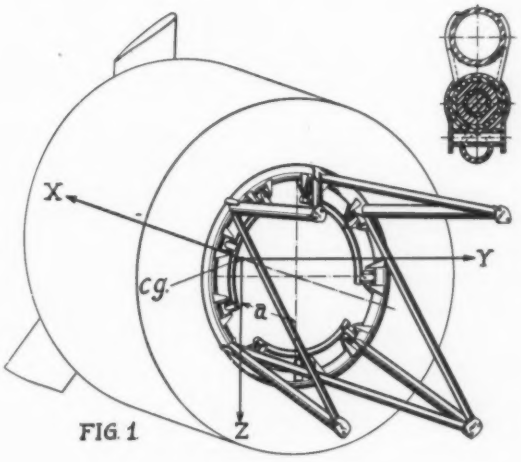

FIG. 1

Vibratory Forces

There are a great many forces acting on an aircraft power plant to cause vibration. Such forces result from inherent unbalance of the engine, unavoidable unbalance of the running propeller, and unbalanced air forces acting on the propeller due chiefly to small variations of pitch setting between various blades. The case of two bladed propellers which produce vibration due to aerodynamic forces and gyroscopic couples will not be considered here.

A set of rectangular coordinates fixed to the aircraft are chosen so that the origin is at the center of gravity of the power plant and so that the X axis extends forward along the equilibrium position of the propeller axis with Y to the right and Z down as shown in Fig. 1.

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Below are listed the frequencies of principal vibratory forces for a radial engine of h cylinders driving a propeller of b blades at a speed of pn revolutions per second where n is the speed of revolution of the engine. Forces which are likely to be large are in bold face type.

	From Engine	From Propeller
Forces along X	none	none
Forces along Y and Z	n, $\mathbf{2n}$, $4n$	pn
Torques about X	$n/2$, $\mathbf{n}$, $2n$, $[(hn/2) - 1]$ $\mathbf{hn/2}$, $[(hn/2) + 1]$, hn	none
Torques about Y and Z	n, $\mathbf{2n}$, $4n$	$\mathbf{pn}$, $\mathbf{bpn}$, $2bpn$

The vibratory forces and torques due to the acceleration of parts of the engine may be found from references 1 and 7. Reference 2 gives the vibratory torques due to explosion forces. Forces and torques at the propeller speed, pn, are due to what might be termed inaccuracies of manufacture of the propeller, namely, static and dynamic unbalance and variation of pitch between blades. Even with carefully constructed propellers, these forces are usually more troublesome than engine unbalance. The forces at multiples of propeller blade frequency; bpn, $2bpn$, are due to nonuniformity of the air stream entering the propeller disc.

Since the power plant has six degrees of freedom, it may have six different natural frequencies, and it is not surprising that with the conventional relatively rigid engine mount, one or more of these natural frequencies usually resonates with one or more of the numerous forcing frequencies within the operating speed range, resulting in high vibratory amplitudes of the power plant and the transmission of large vibratory forces to the aircraft structure.

Vibration Isolation

These forces may be greatly reduced by application of the principle of vibration isolation; that is, by designing the structure so that the unbalanced forces will cause corresponding accelerations in a part of the apparatus (in this case the power plant) and will leave the remainder of the structure virtually undisturbed. It is often erroneously assumed that vibratory motion of the power plant will be increased by introduction of the flexibility which is required for proper vibration isolation and that the use of such a flexible structure will therefore be likely to cause failures in the propeller or accessories. On the contrary, a proper structure for vibration isolation will avoid resonance which is commonly present in conventional structures and will result in much lower accelerations of the power plant and reduced stresses in the accompanying equipment.

It can easily be shown[3,4] that isolation of vibratory forces in the case of a system of one degree of freedom is obtained by making the natural frequency of the system small compared to the frequency of the exciting force. If the exciting force contains more than one frequency, only the lowest need be considered. Large damping is neither essential nor desirable in cases where the applied vibratory forces are not irregular. In the case of a system of many degrees of freedom, vibration isolation is obtained if the natural frequency of each mode of vibration is small compared to the lowest frequency of any force which will excite the mode in question.

Elastic Restraint of a Rigid Body

A displacement of a rigid body in space is determined by a minimum of six coordinates. If the rotation of the body is small, the coordinates may be X, Y, and Z, the displacement of some point in the body (generally the center of gravity) and ϕ, θ, ψ representing small rotations of the body about each of the coordinate axes, respectively. The limitation that the rotations are small is necessary with this coordinate system so that rotations will be commutative. If the spring restraints are linear, the components of the restoring force, F, and of the restoring torque, T, in terms of the displacement then are:

$$\left.\begin{aligned}
-F_x &= a_{11}x + a_{12}y + a_{13}z + a_{14}\phi + a_{15}\theta + a_{16}\psi \\
-F_y &= a_{21}x + a_{22}y + a_{23}z + a_{24}\phi + a_{25}\theta + a_{26}\psi \\
-F_z &= a_{31}x + a_{32}y + a_{33}z + a_{34}\phi + a_{35}\theta + a_{36}\psi \\
-T_x &= a_{41}x + a_{42}y + a_{43}z + a_{44}\phi + a_{45}\theta + a_{46}\psi \\
-T_y &= a_{51}x + a_{52}y + a_{53}z + a_{54}\phi + a_{55}\theta + a_{56}\psi \\
-T_z &= a_{61}x + a_{62}y + a_{63}z + a_{64}\phi + a_{65}\theta + a_{66}\psi
\end{aligned}\right\} \quad (1)$$

In this case there are 36 constants which may be reduced to 21 *independent* constants by the application of Maxwell's theorem. It appears that there is little to be gained by a change in the coordinate axes. In the first place, only six independent coefficients could possibly be eliminated by choice of axes, which would leave a minimum of 15 constants aside from the orientation and position of the axes. Secondly, simplification of the specification of dynamical properties of the rigid body requires that the axes chosen should be the principal axes of inertia of the body. Thus an attempt to simplify the statical problem by choice of axes will merely store up difficulty for later analysis. It is evident that a general solution for free vibration of an elastically supported body involves the solution of an equation of the sixth or higher degree. Fortunately it is unnecessary to attempt the general solution since certain special cases give more desirable vibration characteristics.

The Conventional Engine Mount[7,8,9,10]

The striking success of the automobile engine mounting which was made flexible about the crankshaft axis caused designers of aircraft engine mountings to concentrate their attention on isolation of torsional

oscillation about the propeller shaft axis, forgetting that in the case of the aircraft power plants there are large vibratory torques about axes perpendicular to the crankshaft which are notably absent in the case of automobile engines. Fig. 1 is a diagrammatic sketch of the conventional engine mount. Because of its axial symmetry, the solution of the equations of motion of the conventional mount is much simpler than the general case.

The elastic forces acting on the power plant reduce to:

$$\left.\begin{aligned} -F_x &= a_{11}x, & -T_x &= a_{44}\phi \\ -F_y &= a_{22}y + a_{26}\psi, & -T_y &= a_{55}\theta + a_{35}z \\ -F_z &= a_{33}z + a_{35}\theta, & -T_z &= a_{66}\psi + a_{26}y \end{aligned}\right\} \quad (2)$$

From symmetry:

$$a_{22} = a_{33},\ a_{55} = a_{66},\ a_{35} = a_{26}$$

The result of such elastic restraint on a body with axial symmetry about OX, such as a radial engine, is to produce two independent modes of vibration, translation along the X axis with a frequency ω_1 and oscillation about OX with a frequency ω_4 and two pairs of coupled vibratory modes with frequencies ω_{26}, ω_{62}. In terms of the natural frequencies of translation along the Y, (Z) axis ω_2, (ω_3) and of oscillation about the Z, (Y) axis ω_6, (ω_5), when the coupling term is reduced to zero, the coupled mode frequencies are:

$$\omega_{62}^2 = {}^1/_2[\omega_2^2 + \omega_6^2 + (a^2/k^2)\omega_2^2] + {}^1/_2\sqrt{[\omega_2^2 + \omega_6^2 + (a^2/k^2)\omega_2^2]^2 - 4\omega_2^2\omega_6^2} \quad (3)$$

$$\omega_{62}^2 = {}^1/_2[\omega_2^2 + \omega_6^2 + (a^2/k^2)\omega_2^2] - {}^1/_2\sqrt{[\omega_2^2 + \omega_6^2 + (a^2/k^2)\omega_2^2]^2 - 4\omega_2^2\omega_6^2} \quad (4)$$

where k is the radius of gyration of the body about the Y or Z axis, and $a = a_{26}/a_{22}$ is the "overhang" or distance from the plane of the mounting springs to the center of gravity (Fig. 1).

The frequency spread may be minimized by setting $\omega_6^2 = [1 + (a^2/k^2)]\omega_2^2$ but in the case of a normal single or two row radial engine

$$.75 > a^2/k^2 > .50 \quad \text{and} \quad 2.23 > \omega_{62}/\omega_{26} > 1.93$$

Thus the minimum spread is about two to one.

Shortcomings of the Conventional Mount

The spread of natural frequencies is in itself undesirable. If the higher frequency is left well below the lowest exciting frequency in order to obtain good vibration isolation, the lower frequency will be unnecessarily low. This results in excessive deflections under static loads and transient conditions, and requires an unnecessarily large quantity of elastic material (usually rubber). The advent of large two row engines with extended shafts carrying heavy propellers operating below 1000 r.p.m. has introduced proportionately greater overhang and correspondingly increased power plant vibration.

The two modes of vibration corresponding to the two natural frequencies ω_{26} and ω_{62} are, respectively, oscillation about an axis perpendicular to the axis of symmetry and intersecting it at a point behind the plane of the mount, and oscillation about a similar axis intersecting the axis of symmetry at a point on the opposite side of, and closer to, the power plant center of gravity. It will be noted that the node having the higher frequency has also a greater proportion of rotation (since the node is nearer the center of gravity). This is an unfortunate circumstance inasmuch as this node will be particularly excited by dynamic unbalance and aerodynamic moments of the propeller which are at a low frequency. Furthermore, it may be shown that the effect of gyroscopic forces from the propeller is to split each of these natural frequencies into two, one higher and one lower than the frequency without gyroscopic forces, accentuating the spread of frequencies.

It is desirable, in any case, to eliminate coupling between translational and rotational motions because rotational motions will be practically unaffected by airplane accelerations such as are encountered in take-off, landing, and rough air, and if elastic coupling is eliminated it is possible to use a structure which allows the rotational flexibility necessary for good isolation without requiring a large amount of rubber and without resulting in large amplitudes of transient motion. Placing the elastic mounting members in the YZ plane is an obvious solution for decoupling and makes $\omega_6/\omega_2 \leqq 1$ a possibility; however the practical complications introduced by the requisite supporting structure precludes its serious consideration. Further study of the nature of elastic supporting members revealed that a very simple combination of specially designed elastic members may be arranged to produce a system characterized by the absence of elastic coupling, and easily made to have all the free vibration characteristics which are desirable in an aircraft power plant without changing the general arrangement of the engine mount structure or the engine itself. A general consideration of the nature of individual elastic supporting members follows.

Elastic Restraint of a Point

Consideration of the elastic restraint of a point will be limited to the linear case. For a concrete picture, visualize several linear springs radiating from a common point of intersection to fixed outer ends. If a set of fixed rectangular axes passing through the equilibrium position is chosen to describe the position of the intersection point, the force in all the springs due to a small displacement x, y, z, of the point may be resolved into components along these axes and added, with the result that the components of the restoring force, f, may be expressed in terms of the components of displacement as follows:

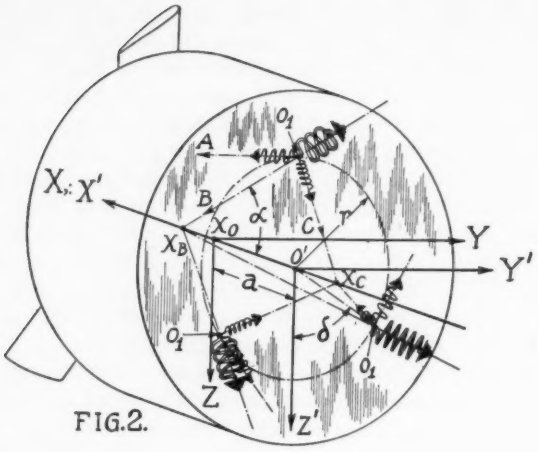


FIG. 2.

$$\left.\begin{aligned} -f_x &= k_{11}x + k_{12}y + k_{13}z \\ -f_y &= k_{21}x + k_{22}y + k_{23}z \\ -f_z &= k_{31}x + k_{32}y + k_{33}z \end{aligned}\right\} \quad (5)$$

where $k_{11}, k_{12} \ldots . k_{33}$ are constants depending upon the stiffness and arrangement of the springs. The potential energy, V, stored in the springs is

$$-V = \int f_x dx + \int f_y dy + \int f_z dz$$

and if $V = 0$ when $x = y = z = 0$

$$V = {}^1/_2 k_{11}x^2 + {}^1/_2 k_{22}y^2 + {}^1/_2 k_{33}z^2 + 2k_{12}xy + 2k_{23}yz + 2k_{13}zx \quad (6)$$

If V = unity, the resulting surface of the second degree representing constant potential energy is an ellipsoid. Since $\vec{f} = -\text{grad } V$, this ellipsoid may be interpreted in terms of physical quantities as follows. The restoring force for a displacement along a radius vector is parallel to the normal to the surface of the ellipsoid at the intersection of the radius vector. The force is proportional to the displacement and inversely proportional to the square of the length of the radius vector to the surface. There are, in general, three directions at right angles, the principal axes of the ellipsoid, characterized by the property that a force along one of these directions will cause a displacement *in the same direction*. These directions will be called "principal elastic axes." If the axes of coordinates are rotated so as to coincide with the principal axes of the energy ellipsoid,

$$V = {}^1/_2 k_A A^2 + {}^1/_2 k_B B^2 + {}^1/_2 k_C C^2 \quad (7)$$

where A, B, and C, are the displacements in the new coordinate system.

Eliminating Elastic Coupling

Consider a radial engine supported by elastic means at the conventional points (Fig. 2). At each of the mounting points is an elastic member having three principal elastic axes A, B, and C with corresponding spring rates k_A, k_B, and k_C. The elastic members are symmetrically disposed with the A axis of each member tangential to the circle of the mounting points, the B and C axes of each member intersect the X' axis at common points X_B and X_C as shown on Fig. 2, whereupon the mounting points lie in the Y', Z' plane. According to the notation in this figure, the angle $O'X_BO_1$ is α and the angle $O_1O'Z'$ is δ.

The direction cosines of the A, B, C axes are given by the following scheme:

	A	B	C
X'	0	$-\cos\alpha$	$-\sin\alpha$
Y'	$-\cos\delta$	$-\sin\alpha\sin\delta$	$\cos\alpha\sin\delta$
Z'	$-\sin\delta$	$\sin\alpha\cos\delta$	$-\cos\alpha\cos\delta$

A parallel displacement Δz of the engine along the Z' axis will result in forces along the A, B, C axes as follows:

$$\left.\begin{aligned} f_A &= -k_A(-\sin\delta)\Delta z \\ f_B &= -k_B(\sin\alpha\cos\delta)\Delta z \\ f_C &= -k_C(-\cos\alpha\cos\delta)\Delta z \end{aligned}\right\} \quad (8)$$

The corresponding components of force along the $X'Y'Z'$ axes are

$$\begin{aligned} f_X' &= (k_B\sin\alpha\cos\alpha\cos\delta - k_C\sin\alpha\cos\alpha\cos\delta)\Delta z \\ f_Y' &= (-k_A\sin\delta\cos\delta + k_B\sin^2\alpha\sin\delta\cos\delta + k_C\cos^2\alpha\sin\delta\cos\delta)\Delta z \\ f_Z' &= (-k_A\sin^2\delta - k_B\sin^2\alpha\cos^2\delta - k_C\cos^2\alpha\cos^2\delta)\Delta z \end{aligned} \quad (9)$$

The sum of the forces from m elastic units equally spaced on the mount circle;

$$\begin{aligned} \delta &= 2\pi/m, 4\pi/m \ldots . (2m\pi/m) + \text{constant} \\ F_X' &= \Sigma f_X' = 0 \\ F_Y' &= \Sigma f_Y' = 0 \\ F_Z' &= \Sigma f_Z' = -\frac{m}{2}(k_A + k_B\sin^2\alpha + k_C\cos^2\alpha)\Delta z \end{aligned} \quad (10)$$

The fact that $F_X' = 0$ and $F_Y' = 0$ for a displacement along Z' could also be inferred from symmetry.

Similarly, it may be shown that the torques T_x' and T_z' about the X' and Z' axes, respectively, are zero for a displacement Δz, while

$$T_y' = \frac{mr}{2}(k_B - k_C)(\sin\alpha\cos\alpha)\Delta z, \text{ where } r = \overline{O'O_1}.$$

It appears, therefore, that the force resulting from displacement Δz is parallel to Z' and intersects the X' axis at a point X_0 given by:

$$a = \overline{O'X_0} = \frac{T_y'}{F_z'} = \frac{r(k_B - k_C)\sin\alpha\cos\alpha}{k_A + (k_B - k_C)\sin^2\alpha + k_C}$$

$$\frac{a}{r} = {}^1/_2\frac{\sin 2\alpha}{\dfrac{k_A + k_C}{k_B - k_C} + \sin^2\alpha} = {}^1/_2\frac{\sin 2\alpha}{\dfrac{1 + L_2}{L_1 - L_2} + \sin^2\alpha} \quad (11)$$

where $L_1 = k_B/k_A$ and $L_2 = k_C/k_A$.

When the center of gravity of the power plant is located at X_0 elastic coupling between Z and θ has been eliminated. It may also be shown (as might be inferred from symmetry) that the other motions are also decoupled and for the axes X, Y, Z (parallel to X', Y', Z' with origin at X_0)

$$\left.\begin{aligned} F_x &= -a_{11}x, \quad F_y = -a_{22}y, \quad F_z = -a_{33}z \\ T_x &= -a_{44}\phi, \quad T_y = -a_{55}\theta, \quad T_z = -a_{66}\psi \end{aligned}\right\} \tag{12}$$

It may be shown that the spring constants are:

$$a_{11} = mk_A(L_1 \cos^2 \alpha + L_2 \sin^2 \alpha) \tag{13}$$

$$a_{22} = a_{33} = \frac{m}{2} k_A(1 + L_1 \sin^2 \alpha + L_2 \cos^2 \alpha) \tag{14}$$

$$a_{44} = mr^2k_A \tag{15}$$

$$a_{55} = a_{66} = \frac{m}{2} r^2k_A\left[\left(\frac{a}{r}\right)^2 + L_1\left(\cos \alpha - \frac{a}{r}\sin \alpha\right)^2 + L_2\left(\sin \alpha + \frac{a}{r}\cos \alpha\right)^2\right] \tag{16}$$

While the quantities $a_{11}, \ldots a_{66}$ are not all independent, there is sufficient freedom in the choice of mk_A, L_1, L_2, and r so that the values of all but a_{11} may be established to give desirable vibration isolation. Since there is practically no exciting force along the X axis the value of a_{11} has little effect on transmitted vibration.

With the usual limitations on the mount circle radius, r, it is found that the value of L_2 must be very small. A very simple method of getting desirable values of L_1 and L_2 is by the use of a tube-form adhesion rubber spring ("Lord" bushing) forming one end of a shackle as shown in Fig. 3. With this arrangement the value of L_2 may be reduced virtually to zero, which gives a particularly practical and interesting case of elastically decoupled suspension. Carrying this idea still further, it is possible to construct a strut having axial stiffness but virtually no stiffness in any direction at right angles to the axis. Two such struts arranged to intersect at an angle γ (shown in Fig. 4) will give restraint equivalent to a shackle having its rubber at the intersection point of the two struts and having

$$L_1 = \cot^2 (\gamma/2) \tag{17}$$

In addition to giving control of L_1, the center lines of the struts may be made to intersect at points which are inaccessible. The shackle type and the strut type of mounting units have both been found useful (Figs. 3 and 4).

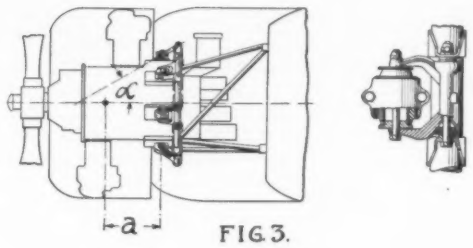


FIG. 3.

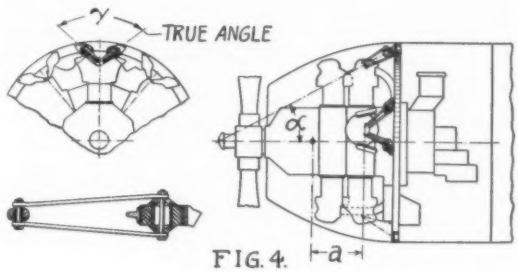


FIG. 4.

Dynamics of Elastically Decoupled Engine Mounts

The vibratory motions of a flexibly mounted aircraft power plant are determined by three classes of forces: (1) forces that vary with time which have already been mentioned, (2) forces that vary with position including the elastic restoring forces, already covered in detail, and aerodynamic forces from the propeller, (3) forces that vary with velocity including friction and gyroscopic moments. The latter two classifications are particularly important because they determine the free vibration characteristics and stability of the power plant. When the axis of a propeller is displaced to make a small angle with the direction of the relative wind, air forces on the propeller generate a moment tending to rotate the propeller axis at right angles to this displacement, and also cause a force normal to the propeller axis in the plane of the displacement; both are proportional to the angle. These aerodynamic forces and moments may be computed by the methods of reference 5 or from the measurements of reference 6. The gyroscopic moment of a propeller is at right angles to the propeller axis and is normal and proportional to the rate-of-change of the direction of the axis. The above moments result in coupling between oscillations about the Y and Z axes. It might appear that there was also coupling between translation and rotation due to the fact that a rotation, $\Delta\theta$, causes a force along the Z axis. This, however, is not the case since there is no corresponding torque due to a translation Δz. The forces along Z and Y due to rotations $\Delta\theta$ and $\Delta\psi$ merely act as a part of the forcing function along these directions.

The motions θ and ψ alone are coupled, and the equations of motion may be written,

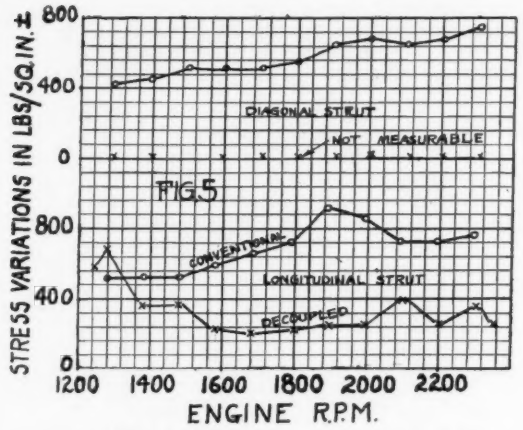
$$\left.\begin{aligned} \ddot{\theta} + C_1\dot{\theta} + C_2\theta - C_3\dot{\psi} - C_4\psi &= T_\theta(t) \\ \ddot{\psi} + C_1\dot{\psi} + C_2\psi + C_3\dot{\theta} + C_4\theta &= T_\psi(t) \end{aligned}\right\} \tag{18}$$

C_1I_y = damping torque about Y, (Z) for one radian per second velocity, $\dot{\theta}$, ($\dot{\psi}$)

$C_2 = (a_{55} - \rho p^2 n^2 D^4 C_f d)/I_y$

$C_3 = 2\pi p n I_p/I_y$

$C_4 = \rho p^2 n^2 D^5 C_M/I_y$



Comparison of vibratory stress in engine mount members measured in flight with conventional and decoupled mounting (same rubber springs).

$T_\theta(t), T_\psi(t)$ = forcing torques about Y and Z, respectively

ρ = atmospheric density

pn = propeller revolutions per second

$I_y = I_z$ = moment of inertia of complete power plant about an axis normal to OX through O

I_p = polar moment of inertia of the propeller

D = propeller diameter

$\rho p^2 n^2 D^4 C_F$ = aerodynamic force normal to Z, (Y) and propeller axis per radian θ, (ψ) displacement

d = distance from plane of propeller to power plant c.g.

$\rho p^2 n^2 D^5 C_M$ = aerodynamic torque about the Z, (Y) axis per radian θ, (ψ) displacement

The vibration response characteristics are determined by the complementary function of the solution of Eqs. (18) and may be found by setting

$$\theta = A_1 \epsilon^{\beta t} \quad \text{and} \quad \psi = A_2 \epsilon^{\beta t} \tag{19}$$

where A_1 and A_2 and β may be complex.

The resulting biquadratic gives four values of β;

$$\left.\begin{aligned} \beta_{1,2} &= -\frac{C_1}{2} + \frac{1}{2}(C_5^2 + C_6^2)^{1/4} \cos\frac{\lambda}{2} \pm \\ &\quad i\left[-\frac{C_3}{2} + \frac{1}{2}(C_5^2 + C_6^2)^{1/4} \sin\frac{\lambda}{2}\right] \\ \beta_{3,4} &= -\frac{C_1}{2} - \frac{1}{2}(C_5^2 + C_6^2)^{1/4} \cos\frac{\lambda}{2} \pm \\ &\quad i\left[-\frac{C_3}{2} - \frac{1}{2}(C_5^2 + C_6^2)^{1/4} \sin\frac{\lambda}{2}\right] \end{aligned}\right\} \tag{20}$$

where $C_5 = C_1^2 - 4C_2 - C_3^2$

$C_6 = 2C_1C_3 - 4C_4$

$\lambda = \tan^{-1} C_6/C_5$

The condition for stability is that the real part of β is not positive, or

$$\frac{C_1}{2} \geqq \left(\frac{\sqrt{2}}{4}\right)[(C_5^2 + C_6^2)^{1/2} + C_5]^{1/2} \tag{21}$$

It will be noted that if there is no damping ($C_1 = 0$) the motion is unstable.

The two natural frequencies are given by the two positive values of the imaginary part of β

$$\omega_{55}, \omega_{56} = \left|\frac{C_3}{2} \pm [(C_5^2 + C_6^2)^{1/2} + C_5]^{1/2}\right| \tag{22}$$

Care must be taken to work out the parentheses in Eqs. (21) and (22) from the inside and to take always the positive root.

Substitution of actual values of the constants C_2, C_3, C_4 shows that in the practical case a *very small amount of damping will prevent instability* and that the natural frequencies are essentially the same as if $C_1 = C_4 = 0$ in which case,

$$\omega_{55}, \omega_{56} = \sqrt{(C_3/2)^2 + C_2} \pm C_3/2 \tag{23}$$

Since without gyroscopic moments ($C_3 = 0$), $\omega_{56} = \sqrt{C_2}$, the effect of such forces in spreading the frequencies is evident from Eq. (23).

Using the lower frequency it may be found that $A_1/A_2 = -1$, while for the higher frequency $A_1/A_2 = +1$; thus the higher frequency represents a precession of the axis in the direction of propeller rotation and the lower frequency a precession in the opposite direction. For positive propeller rotation, C_3 is positive. At a given propeller speed, C_4 is negative at low flight speed, increasing to zero at about the forward speed for maximum efficiency and further increasing to a maximum value at approximately the speed at which the propeller torque becomes zero. The maximum and minimum values of C_M are approximately .022 and $-.010$, respectively.[6] The low-frequency reverse-rotating precession tends to become unstable when C_4 is positive. It has not been found possible to produce this type of self-excited vibration in aircraft installations although it appeared in a model carefully constructed to avoid friction. Addition of an extremely small amount of friction made the model stable.

With the values of the constants C_1, C_2, C_3, and C_4 which occur in practice, the higher frequency forward-rotating precession is stable even when C_1 approaches 0.

Practical Applications and Results

A number of elastically decoupled flexible mounts have been made in accordance with the above analysis. The natural frequencies of these mounts have been selected so that the highest resonant speeds would group around 800 engine r.p.m. In addition to the

factors considered in the above analysis, it has been found necessary to modify the elastic support slightly to allow for elasticity in the airplane structure, and in the case of high-powered small machines it is necessary to make corrections due to the fact that the mass of the airplane is not large compared to the mass of the power plant.

The airplanes so far fitted with decoupled elastic engine mounts have been characterized by extraordinary freedom from vibration throughout the speed range from low speed cruising to take-off r.p.m. Furthermore, the maximum excursions of the power plant due to transients such as occur in starting, accelerating, and maneuvering are not objectionally greater than with the conventional mount.

Fig. 5 is a record of the stress in one of the engine support struts with conventional and decoupled mounting showing how effectively vibration of the power plant has been isolated.

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Errata

In the article on "Gas Pressure Torque of Radial Engines" by G. P. Bentley and E. S. Taylor in the November issue of the Journal, four of the figures on page 4 were inadvertently transposed. The figure captions are properly placed but the plots of Figs. 5 and 9 are transposed and those of Figs. 7 and 11 are transposed.

Portions of the "Table of Contents" of the November issue of the Journal are in error because the printer failed to notice a rearrangement of the material in the page proofs. To correct these errors add 2 to the page numbers of the "Book Reviews" and "Exchanges," and subtract 4 from the page numbers of "Institute Notes" and "Books Received."

Flight Analysis of a Sounding Rocket with Special Reference to Propulsion by Successive Impulses

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SUMMARY

In Part I of this paper an exact solution of the problem of determining the height reached by a body in vertical flight *in vacuo* propelled by successive impulses is presented. On the basis of this analysis it is concluded that a rocket propelled by successive impulses—the impulses being obtained, for example, from rapidly burning powder—can theoretically reach much greater heights than is possible by sounding balloons and, therefore, further experimental research is justified. In Part II the effect of the variation of the acceleration of gravity with height above sea level on the flight performance of a sounding rocket is analyzed. For a 1000 mile sounding rocket the decrease in gravitational pull accounts for a 25 percent increase in the maximum height reached over that calculated on the basis of a constant gravitational acceleration. In Part III the fundamental performance equation for flight of a sounding rocket in air is expressed in terms of dimensionless parameters and factors and their physical significance is discussed. Finally, in Part IV the theory of the preceding sections is applied to a specific case of a sounding rocket propelled by successive impulses which are supplied by a reloading type of powder rocket motor.

INTRODUCTION

IN 1919, R. H. Goddard[1] published the historically important paper which suggested the use of nitrocellulose powder as a propellant for raising a sounding rocket to altitudes beyond the range of sounding balloons. To determine the feasibility of this propellant, a series of experiments had been carried out and it was found that a thermal efficiency of 50 percent could be expected if the powder was exploded in a properly designed chamber and the resulting gases were allowed to escape at high velocity through an expanding nozzle. In 1931, R. Tilling used a mixture of potassium chlorate and naphthalene as propellant and actually reached an altitude of 6600 feet. More recently, L. Damblanc[2] made static tests with a slow burning black powder and from these estimated that a height of 10,000 feet could be reached using a two-step arrangement. The results so far reported offer an incentive to further analysis.

The propulsion obtained by the use of powder charges in a rocket motor, which are supplied by a reloading mechanism, is referred to in this paper as propulsion by successive impulses. This type of propulsion is essentially different from the type of propulsion made available by a rocket motor which continuously burns a combustible mixture at constant pressure. The thrust of the latter rocket motor is nearly constant, whereas in the former case, due to the rapidness of the combustion of the powder charges, the propulsion consists of a series of uniform impulses.

The effect of decreasing gravitational acceleration on the maximum height reached by a rocket has been considered by A. Bartocci.[3] However, he assumes that the rocket itself has a constant acceleration during powered flight. L. Breguet and R. Devillers[4] also considered the effect of the variation of g. To simplify the analysis, they assumed that the acceleration of the rocket was equal to a constant multiple of g. Since the sounding rocket will be propelled by a nearly constant thrust or a uniform rate of successive impulses, in Part II the authors have studied the problem anew according to this mode of propulsion.

When the sounding rocket is ascending through the air the maximum height reached is less than that reached for flight *in vacuo*. Recently, studies have been made of the problem by W. Ley and H. Schaefer[5] and by F. J. Malina and A. M. O. Smith.[6] On the basis of the latter study a group of new performance parameters and factors have been isolated from the general performance equation, and these are discussed in Part III.

NOTATION

Referring to Fig. 1, the following notation has been used throughout the paper:

w = weight of propellant and propellant container ejected per impulse, lbs.
k = ratio of propellant container weight to sum of container and propellant weight ejected per impulse.
λ = $(1 - k)$.
W_0 = initial weight of rocket, lbs.
M_0 = initial mass of the rocket, slugs.
W_r = instantaneous weight of rocket, lbs.
ζ = ratio of initial weight of propellants to initial total weight of a rocket propelled by constant thrust.
ζ_1 = ratio of initial weight of propellants to initial total weight of a rocket propelled by successive impulses.
ζ_1' = ζ_1/λ.
n = number of impulses per second.
N = total number of impulses occurring during powered flight.

t = time, sec.
Δt = interval between impulses, sec.
a_0 = initial acceleration imparted to rocket, ft. per sec.^{2}
g_0 = acceleration of gravity at the starting point of flight, ft. per sec.^{2}
g = acceleration of gravity above the starting point of flight, ft. per sec.^{2}
c = effective exhaust velocity of ejected propellant, ft. per sec.
v = instantaneous velocity, ft. per sec.
Δv_r = velocity imparted to rocket by the rth impulse, ft. per sec.
v_r' = velocity at end of the rth interval, ft. per sec.
v_{s_0} = velocity of sound corresponding to atmospheric conditions at the starting point of flight, ft. per sec.
v_s = velocity of sound corresponding to atmospheric conditions at height reached by the rocket at time t, ft. per sec.
B = Mach's number $= v/v_s$.
$V_{max.}$ = velocity of rocket at start of coasting flight, ft. per sec.
$V_{max._0}$ = velocity of rocket at start of coasting flight if g is constant and equal to g_0, ft. per sec.
h = altitude above sea level, feet.
h_r = height reached at the beginning of the rth interval, feet.
h_r' = height reached at the end of the rth interval, feet.
H_P = height traveled during powered flight, feet.
H_{P_0} = height traveled during powered flight, if g is constant and equal to g_0, feet.
H_C = height traveled during coasting flight, feet.
H_{C_0} = height traveled during coasting flight, if g is constant and equal to g_0, feet.
$H_{max.}$ = height traveled during powered flight and coasting flight, feet.
$H_{max._0}$ = height traveled during powered flight and coasting flight, if g is constant and equal to g_0, feet.
R = radius of earth, 2.088×10^8, feet.
D = drag on rocket due to air resistance, lbs.
C_D = drag coefficient of rocket.
$C_D{}^*$ = drag coefficient of rocket at velocity of sound.
Λ = drag-weight factor (discussed in the section on the effect of air resistance).
ρ_0 = mass density of air at the starting point of flight, slugs per cu.ft.
σ = ratio of air density at altitude to air density at the starting point of flight.
T = absolute temperature of atmosphere at the height reached by the rocket at time t, °F.
T_0 = absolute temperature of atmosphere at the starting point of flight, °F.

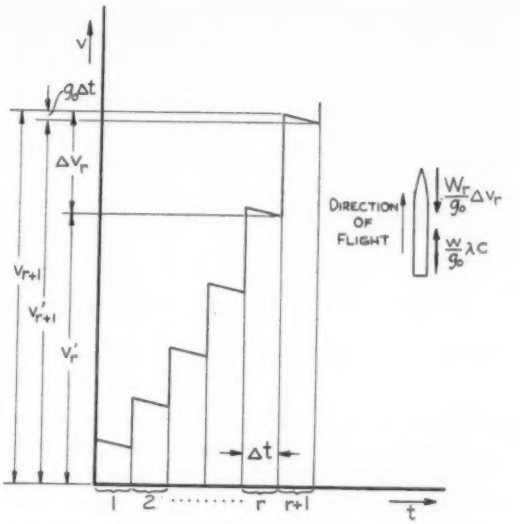


FIG. 1. Variation of the flight velocity v with the time t.

A = largest cross-sectional area of rocket shell, sq.ft.
d = largest diameter of rocket shell, ft.
l = length of rocket shell, ft.

I

An approximate method of calculating the maximum height reached by a rocket propelled by powder was developed by R. H. Goddard.[1] To simplify the analysis a continuous loss of mass was assumed and the problem was so stated, that a minimum mass of propellant necessary to lift one pound of mass at the end of the flight to any desired height was determined. However, if high-powered powder is used, the rate of burning is so rapid that the propulsive action is instantaneous. The rocket is thus acted upon by an impulse rather than by a constant thrust.

In the following analysis, it has, therefore, been assumed that the propulsive force is an impulsive force, *i.e.*, the force acts for such a brief interval of time that the rocket does not change its position during the application of the force, although its velocity and its momentum receive a finite change. If the combustion process of the propulsive unit takes place at constant volume this assumption is justified. Further, a study of interior ballistics of small arms reveals that the period between the ignition of the powder charge and the bullet's arrival at the end of a two-foot barrel is of the order of 14 ten-thousandths of a second. If the gases are not restrained and their travel through the burning chamber and the nozzle is of much shorter length, as is the case for the rocket motor, even shorter periods of duration of action can be expected.

Assuming that the propulsive force acts as an impulse, then the motion of the rocket can be calculated by Newton's third law, which states that

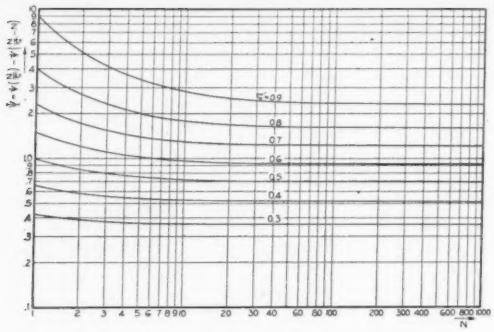


FIG. 2. Variation of Ψ with N for various values of ζ_1'.

impulses between two bodies are equal and opposite. Hence, equating the momentum of the exhaust gases to the momentum imparted to the rocket, using the quantities defined in the list of notation and referring to Fig. 1, the following relation can be written for flight *in vacuo:*

$$(\lambda w/g_0)c = (W_r/g_0)\,\Delta v_r \tag{1}$$

where

$$\lambda = (1 - k) \quad \text{and} \quad W_r = W_0 - rw \tag{2}$$

or

$$\Delta v_r = \frac{w\lambda c}{W_0 - rw} = \frac{\zeta_1'\lambda c}{N}\left(\frac{1}{1 - r\zeta_1'/N}\right) \tag{3}$$

where

$$\zeta_1' = wN/W_0 = \zeta_1/\lambda$$

During the interval between impulses, Δt, the velocity is reduced by the action of gravity so that at the end of the rth interval, the velocity of the rocket will be

$$v_r' = v_r - g_0\Delta t = v_{r-1}' + \Delta v_r - g_0\Delta t \tag{4}$$

Therefore

$$v_r' = \sum_{s=1}^{s=r} \Delta v_s - rg_0\Delta t \tag{5}$$

Substituting for Δv_s from Eq. (3)

$$v_r' = \frac{\zeta_1'\lambda c}{N}\sum_{s=1}^{s=r}\frac{1}{1 - s(\zeta_1'/N)} - rg_0\Delta t \tag{6}$$

or

$$v_r' = \frac{\zeta_1'\lambda c}{N} S_1 - rg_0\Delta t$$

where

$$S_1 = \sum_{s=1}^{s=r}\frac{1}{1 - s(\zeta_1'/N)}$$

The height gained during each interval will be represented by the area under the velocity curve in the interval, or

$$h_r' - h_r = v_r'\Delta t + {}^1/_2\, g_0(\Delta t)^2 \tag{7}$$

Therefore, at the end of the Nth interval which is the end of the powered flight, the height will be

$$H_{P_0} = \sum_{r=1}^{r=N} v_r'\Delta t + (N/2)g_0(\Delta t)^2$$

Substituting for v_r' its value in Eq. (6)

$$H_{P_0} = \sum_{r=1}^{r=N}\Delta t\left\{\frac{\zeta_1'\lambda c}{N}\sum_{s=1}^{s=r}\frac{1}{1 - s(\zeta_1'/N)} - rg_0\Delta t\right\} + \frac{N}{2}g_0(\Delta t)^2$$

$$= \frac{\zeta_1'\lambda c}{N}\Delta t\sum_{r=1}^{r=N}\frac{N + 1 - r}{1 - r(\zeta_1'/N)} - g_0(\Delta t)^2\sum_{r=1}^{r=N}(r - {}^1/_2)$$

$$= \frac{\zeta_1'\lambda c}{N}\Delta t S_2 - \frac{N^2}{2}g_0(\Delta t)^2 \tag{8}$$

where

$$S_2 = \sum_{r=1}^{r=N}\frac{N + 1 - r}{1 - r(\zeta_1'/N)}$$

The maximum height reached will be the sum of the height at the end of powered flight and the height traveled during coasting or

$$H_{max_0} = H_{P_0} + H_{C_0} = H_{P_0} + V^2_{max_0}/2g_0 \tag{9}$$

To calculate the maximum height one has first to evaluate the sums S_1 and S_2.* Noting that

$$\frac{1}{1 - s(\zeta_1'/N)} = \int_0^\infty e^{-x\{1 - s(\zeta_1'/N)\}}dx$$

S_1 can be written in the form

$$S_1 = \int_0^\infty e^{-x}\sum_{s=1}^{s=r}(e^{x\zeta_1'/N})^s dx = \int_0^\infty e^{-x}\frac{e^{x\zeta_1'/N} - e^{(r+1)\zeta_1'/N}}{1 - e^{x\zeta_1'/N}}dx$$

Putting

$x = Ny/\zeta_1'$, the above intergral becomes

$$S_1 = -\frac{N}{\zeta_1'}\int_0^\infty e^{-Ny/\zeta_1'}\left(\frac{1 - e^{ry}}{1 - e^{-y}}\right)dy = \frac{N}{\zeta_1'}\left\{\psi\left(\frac{}{\zeta_1'}\right) - \psi\left(\frac{N}{\zeta_1'} - r\right)\right\} \tag{10}$$

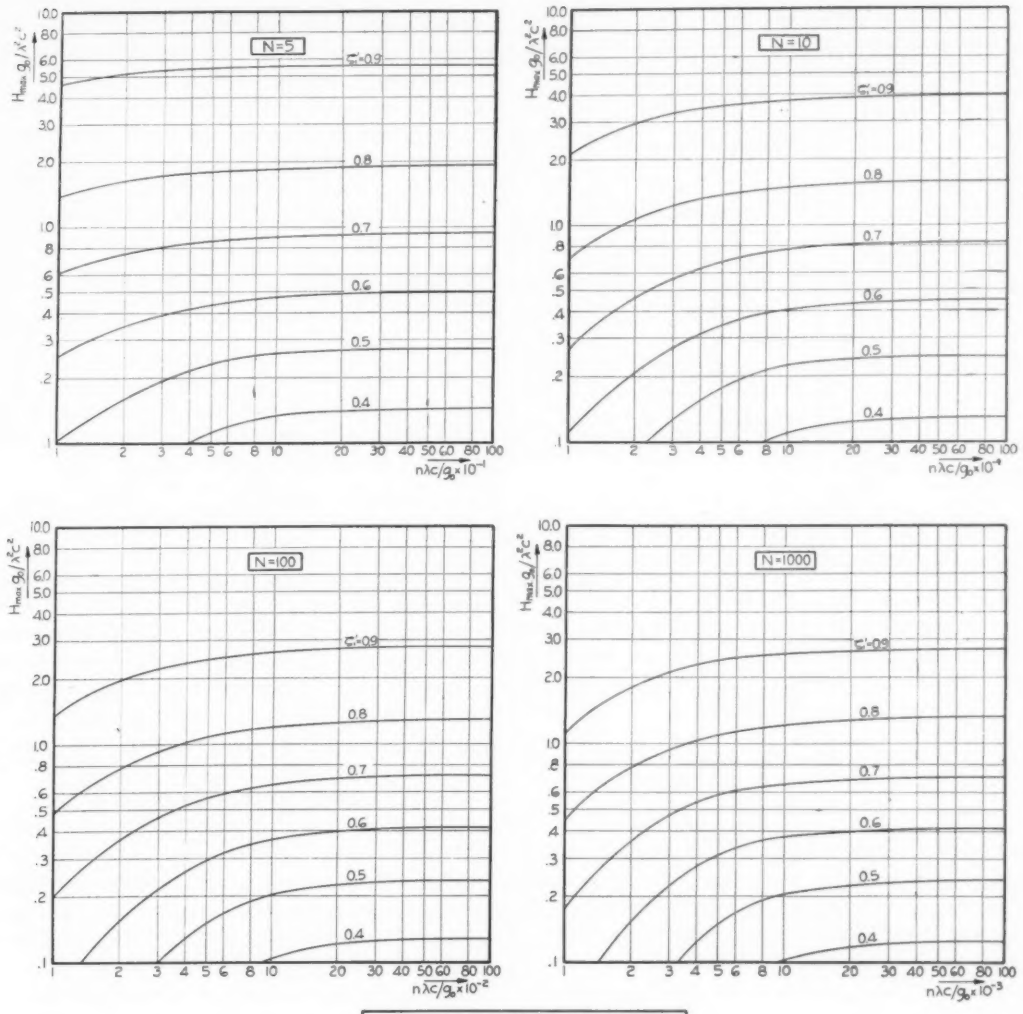
where $\psi(z) = (d/dz)\{\log\Gamma(z)\}$. (The reader is referred to references 7 and 8 for detailed information on this function.) Similarly, S_2 can be summed as

$$S_2 = \frac{N}{\zeta_1'}\left\{N - \left[\frac{N}{\zeta_1'} - (N + 1)\right]\times\left[\psi\left(\frac{N}{\zeta_1'}\right) - \psi\left(\frac{N}{\zeta_1'} - N\right)\right]\right\} \tag{11}$$

Substituting Eqs. (10) and (11) into Eqs. (6) and (8), and then into Eq. (9)

$$H_{max_0} = \frac{\lambda^2c^2}{2g_0}\Psi^2 - \frac{\lambda c}{n}\left\{\left(\frac{N}{\zeta_1'} - 1\right)\Psi - N\right\} \tag{12}$$

* The authors wish to thank Prof. H. Bateman for his suggestion of this method of summing.



$$\frac{H_{max.}g_0}{\lambda^2c^2} = \frac{1}{2}\Psi^2 - \frac{1}{\frac{n\lambda c}{g_0}}\left[\left(\frac{N}{\zeta_1'}-1\right)\Psi - N\right]$$

FIG. 3. $H_{max_0}g_0/\lambda^2c^2$ with nc/g_0 for various values of ζ_1'.

where $n = 1/\Delta t$, and $\Psi = \psi(N/\zeta_1') - \psi[(N/\zeta_1') - N]$.

For convenience of calculation in Fig. 2 the quantity Ψ is plotted against N for different values of ζ_1'.

It can easily be shown that when $N = 1$

$$\Psi = \zeta_1'/(1 - \zeta_1')$$

so that Eq. (12) reduces to

$$H_{max_0} = \frac{\lambda^2c^2}{2g_0}\left(\frac{\zeta_1'}{1-\zeta_1'}\right)^2 \tag{12a}$$

Also, as $N \to \infty$, $\Psi \to -\log(1 - \zeta_1')$, thus Eq. (12) reduces to

$$H_{max_0} = \frac{\lambda^2c^2}{g_0}\left\{\frac{[\log(1-\zeta_1')]^2}{2} + \frac{\zeta_1' + \log(1-\zeta_1')}{(a_0/g_0)+1}\right\} \tag{12b}$$

where

$$a_0 = \frac{\zeta_1'}{N}n\lambda c - g_0 = \frac{nw\lambda c}{W_0} - g_0 \tag{12c}$$

The quantity a_0 can be considered as the initial acceleration of the rocket if $N \to \infty$. It is interesting to notice that Eq. (12b) is the equation obtained by Malina and Smith (Ref. 6) for calculating the maximum height of a constant thrust rocket, as expected.

Fig. 3 shows the variation of $H_{max_0}g_0/\lambda^2c^2$ with $n\lambda c/g_0$ for different values of ζ_1' and for four values of N. These curves show that when the total number of impulses, N, becomes larger than 100, the maximum height reached is imperceptibly changed by increasing the number.

At this point it is necessary to discuss the similarity existing between a rocket propelled by successive

TABLE 1

Successive Impulses

$$H_{max_0} = \frac{\lambda^2 c^2}{g_0}\left\{ {}^1/_2\Psi^2 - \frac{1}{n\lambda c/g_0}\left[\left(\frac{N}{\zeta_1'} - 1\right)\Psi - N\right]\right\}$$

Case	λc Ft. per Sec.	ζ_1'	N	n Impulses per Sec.	H_{max_0} Feet
1	10,000	0.70	326	3	1,472,000
2	10,000	0.70	10	0.092	1,686,000
3	7,000	0.70	326	3	560,000
4	7,000	0.70	10	0.092	676,000

Constant Thrust

$$H_{max_0} = \frac{c^2}{g_0}\left\{ {}^1/_2\,[\log(1-\zeta)]^2 - \frac{1}{a_0/g_0 + 1}\,[\log(1-\zeta) + \zeta]\right\}$$

Case	C	ζ	a_0	H_{max_0} Feet
1	10,000	0.70	32.2	1,468,000
2	10,000	0.70	32.2	1,468,000
3	7,000	0.70	12.9	555,000
4	7,000	0.70	12.9	555,000

impulses and a rocket propelled by constant thrust. The former loses not only the mass of the propellant, but also the containers for the individual charges. The difference in effect on the rocket between the propellant and its containers is that the propellant has an effective exhaust velocity, c, while the ejected containers leave the rocket without appreciable velocity. The propulsive action, however, will remain the same if the whole cartridge, that is, the propellant charge and its container, is considered wholly as propellant, but leaving the motor at a reduced effective exhaust velocity λc. The rocket propelled by constant thrust loses only the mass equal to the propellant carried; therefore, it can be said to be equivalent to the "successive impulses" rocket if its effective exhaust velocity and its total mass of propellant are equal, respectively, to the reduced exhaust velocity and to the sum of the masses of all the containers of the "successive impulses" rocket. In other words, c is equal to λc and ζ is equal to ζ_1'.

In Table 1 the heights for four cases have been calculated to illustrate the effect of the exhaust gas velocity and the total number of impulses given to a rocket whose weight ratio, ζ_1' is 0.70. It will be noticed that for flight *in vacuo* a greater height will be reached if a smaller number of impulses is employed. The lower portion of the Table shows the maximum height reached by an equivalent "constant thrust" rocket for the same four cases with the initial acceleration given by Eq. (12c). The close agreement between the maximum height reached by use of successive impulses, when the total number of impulses exceeds 100, and that reached by the use of constant thrust simplifies the solution of the problem of decreasing acceleration of gravity with height, and enables prediction for flight with air resistance to be based on the results obtained for a rocket propelled by constant thrust (cf. reference 6). These problems are considered in the following sections.

II

It is well known that the acceleration of gravity decreases with the height above the earth's surface according to the following relation:

$$g = g_0[R/(R + h)]^2 \tag{13}$$

At an altitude of 1000 miles the acceleration is only 0.64 times that at sea level. Therefore, for flights up to such altitudes the assumption that g is approximately constant is no longer valid. It was shown by Malina and Smith[6] that a three-step rocket could theoretically reach such an altitude. Thus it is interesting to see how the decrease of g will increase the maximum height reached by the rocket.

First, the effect on powered flight *in vacuo* will be considered and then on coasting flight *in vacuo*. For powered flight the analysis is based on the assumption that the thrust is constant. However, the results can be applied to the case of propulsion by successive impulses if the total number of impulses, N, exceeds 100 as was justified in the previous section.

The equivalent mass of gas flowing per second continuously for the case of successive impulses is

$$wn/g_0 = m \tag{14}$$

Assuming that the rocket starts from rest at sea level, the equation of motion *in vacuo* is

$$\frac{d^2h}{dt^2} = -g_0\left(1 + \frac{h}{R}\right)^{-2} + \frac{mc/M_0}{1 - (m/M_0)t} \tag{15}$$

This is a non-linear differential equation which cannot be solved by usual means. However, for all practical purposes the ratio h/R during powered flight is much smaller than 1, therefore, only first order terms in h/R occurring in the expansions need to be retained. This approximation linearizes the equation to the form

$$\frac{d^2h}{dt^2} = g_0\left(\frac{2h}{R} - 1\right) + \frac{mc/M_0}{1 - (m/M_0)t} \tag{16}$$

The solution of this equation with the initial condition that $h = 0$ and $dh/dt = 0$ when $t = 0$ is

$$h = \frac{R}{2}\left\{1 - \cosh\sqrt{\frac{2g_0}{R}}\,t\right\} + \frac{c}{2\sqrt{2g_0/R}}\left\{e^{\xi u}\int_{\xi}^{\xi u}\frac{e^{-x}dx}{x} - e^{-\xi u}\int_{\xi}^{\xi u}\frac{e^{x}dx}{x}\right\} \tag{17}$$

where $\xi = \sqrt{2g_0/R}\ M_0/m$ and $u = 1 - (m/M_0)t$. At the end of the powered flight, the time is

$$t = t_P = M_0\zeta/m \tag{18}$$

Therefore, the height at the end of the powered flight is

$$H_P = \frac{R}{2}\left\{1 - \cosh\sqrt{\frac{2g_0}{R}}\,\frac{M_0\zeta}{m}\right\} + \frac{c}{2}\sqrt{\frac{R}{2g_0}}\left\{e^{\xi(1-\zeta)}\int_{\xi}^{\xi(1-\zeta)}\frac{e^{-x}dx}{x} - e^{-\xi(1-\zeta)}\int_{\xi}^{\xi(1-\zeta)}\frac{e^{x}dx}{x}\right\} \tag{19}$$

If the hyperbolic cosine term and the integrals are expanded and only first order terms in $1/R$ are retained in consistency with the linearization of Eq. (15), the equation reduces to

$$H_P = -\left\{\frac{\zeta^2 g_0}{2}\left(\frac{W_0}{w}\right)^2 + \frac{\zeta^4 g_0^2}{12R}\left(\frac{W_0}{w}\right)^4\right\} + c\,\frac{W_0}{w}\left\{(1-\zeta)\log(1-\zeta) + \zeta\right\} + \frac{cg_0}{18R}\left(\frac{W_0}{w}\right)^3\left\{6(1-\zeta)^3\log(1-\zeta) + \zeta(11\zeta^2 - 15\zeta + 6)\right\}$$

$$= H_{P_0} + \frac{g_0}{6R}\left(\frac{W_0}{w}\right)^3\left\{\frac{c}{3}\left[6(1-\zeta)^3\log(1-\zeta) + \zeta(11\zeta^2 - 15\zeta + 6)\right] - \frac{\zeta^4 g_0}{2}\left(\frac{W_0}{w}\right)\right\} \tag{20}$$

Differentiating Eq. (17), and substituting the relation of Eq. (18), the maximum velocity at the end of powered flight is

$$V_{max.} = -\sqrt{\frac{Rg_0}{2}}\sinh\sqrt{\frac{2g_0}{R}}\,\frac{M_0\zeta}{m} - \frac{c}{2}\left\{e^{\xi(1-\zeta)}\int_{\xi}^{\xi(1-\zeta)}\frac{e^{-x}dx}{x} + e^{-\xi(1-\zeta)}\int_{\xi}^{\xi(1-\zeta)}\frac{e^{x}dx}{x}\right\} \tag{21}$$

Again expanding and retaining only first order terms in $1/R$, Eq. (21) reduces to

$$V_{max.} = -\left\{\left(\frac{W_0}{w}\right)\zeta + \frac{1}{3}\,\frac{\zeta^3 g_0^2}{R}\left(\frac{W_0}{w}\right)^3\right\} - \left\{c\log(1-\zeta) + \frac{cg_0}{2R}\left(\frac{W_0}{w}\right)^3\left[2(1-\zeta)^2\log(1-\zeta) + 2\zeta - 3\zeta^2\right]\right\}$$

$$= V_{max.0} - \frac{g_0(W_0/w)^2}{R}\left\{\frac{\zeta^3 g_0(W_0/w)}{3} + \frac{c}{2}\left[2(1-\zeta)^2\log(1-\zeta) + 2\zeta - 3\zeta^2\right]\right\} \tag{22}$$

It is seen that the second terms of Eq. (20) and (22) are the corrections to be applied to H_{P_0} and $V_{max.0}$ to account for the variation of the acceleration of gravity. Since both corrections are first order approximations they can be expected to apply approximately also to the case of successive impulses, even when the total number of impulses is less than 100.

The coasting height reached by the rocket due to its velocity at the end of powered flight can be obtained by equating the increase of potential energy during coasting flight to the kinetic energy at the end of powered flight. Thus,

$$\frac{1}{2}\,V_{max.}^2 = g_0\int_{H_P}^{H_P+H_C}\frac{dh}{[1 + (h/R)]^2}$$

or

$$H_C = (H_P + R)\left\{\frac{1}{1 - \dfrac{V_{max.}^2}{2g_0\,[R/(H_P+R)]^2(H_P+R)}} - 1\right\} \tag{23}$$

Putting $V_{max.}^2/2g_0[R/(H_P+R)]^2 = H_{C_0}$, which is the coasting height obtained by assuming a constant gravitational acceleration of the value equal to that at the height H_P, *i.e.*, the height where coasting starts, then Eq. (23) can be written

$$H_C = (H_P + R)\left\{\frac{1}{1 - H_{C_0}/(H_P+R)} - 1\right\}$$

Upon expanding the second term, this equation becomes,

$$H_C = H_{C_0}\left\{1 + \left(\frac{H_{C_0}}{H_P+R}\right) + \left(\frac{H_{C_0}}{H_P+R}\right)^2 + \left(\frac{H_{C_0}}{H_P+R}\right)^3 + \cdots\right\} \tag{24}$$

This equation shows that if the coasting flight starts from sea level, and if the maximum height reached is about 1000 miles, the increase due to the decrease in g is over 25 percent.

III

When the sounding rocket is ascending through the atmosphere instead of *in vacuo*, air resistance comes into play, causing the acceleration of the rocket to be reduced, which decreases the maximum height reached. Since air resistance increases with the air density and with the square of the flight velocity, it is desirable to keep the rocket from ascending too rapidly through the lower layers of the atmosphere where the air density is high. For this reason the optimum initial acceleration will no longer be infinite as shown by Eq. (12b). For the case of constant thrust Malina and Smith[6] have found that the optimum acceleration is around 30 ft. per sec.^{2} For a total number of impulses greater than 100, the difference between propulsion by successive impulses and by constant thrust is very small, so one may expect the above optimum value of initial acceleration to hold for both cases of propulsion.

The actual amount of reduction in maximum height due to air resistance can be calculated by the method of step-by-step integration, if fair accuracy is desired. This integration is carried out by using the fundamental equation for vertical rocket flight which, as given in the previous paper (Ref. 6) is

$$\frac{d^2h}{dt^2} = a = -g + \frac{a_0 + g_0}{1 - t(a_0 + g_0)/c} - \frac{g_0\rho_0\sigma v^2}{2\left[1 - \dfrac{t(a_0 + g_0)}{c}\right]}\frac{C_DA}{W_0} \tag{25}$$

The significance of the ratio C_DA/W_0 was discussed in that paper.[6] Greater significance can, however, be attached to the various terms in the equation if it is transformed into the non-dimensional form

$$\frac{a}{g_0} = -\frac{g}{g_0} + \frac{\dfrac{a_0}{g_0} + 1}{1 - \dfrac{g_0t}{c}\left(\dfrac{a_0}{g_0} + 1\right)} - \frac{\left(\sigma\dfrac{T}{T_0}\right)\left(\dfrac{C_D}{C_D{}^*}B^2\right)\Lambda}{1 - \dfrac{g_0t}{c}\left(\dfrac{a_0}{g_0} + 1\right)} \tag{26}$$

where

$$\Lambda = \frac{\dfrac{\rho_0}{2}C_D{}^*Av_{v_0}{}^2}{W_0}$$

In Eq. (26) appear two types of significant quantities. First, quantities, called "factors," which are constant for any given family of rockets, and second, two quantities called "parameters," one of which is characteristic for a given family of rockets but changes in value along the flight path, and one which depends on the physical properties of the atmosphere. Thus there are the following factors:

a_0/g_0 = ratio of initial acceleration to g_0 ~ "initial acceleration factor," a motor characteristic.

c = exhaust velocity in ft. per sec. ~ "exhaust velocity factor," a motor characteristic.

Λ = "drag-weight factor."

ζ = ratio of weight of combustibles to total initial weight of the rocket ~ "loading factor."

The first two factors, *i.e.*, the "initial acceleration factor" and the "exhaust velocity factor," determine the characteristics of the propelling unit for a given family of rockets while the "drag-weight factor" and the "loading factor" determine the physical dimensions of the rockets. The "drag-weight factor" is a ratio of the drag of the rocket at sea level when traveling with the velocity of sound to the initial weight of the rocket. Since for any given family of rocket shapes the only terms in the factor which can be varied are the maximum cross-sectional area, A, and the initial weight, W_0, it is clear that if the initial weight is doubled then the cross-sectional area must also be doubled to keep the factor the same. The "loading factor" needs to be discussed in some detail as it does not appear explicitly in Eq. (26). Eq. (26) is a differential equation of the flight path which is satisfied at every point along the flight path. The loading factor ζ comes in only when this equation is integrated and the limits of integration are put in. For example, consider two rockets with identical performance factors and parameters, with the exception that one has a ζ of 0.90 and the other has a ζ of 0.50. The flight path of the two rockets will be identical up to the time that 0.50 times the initial weight of the rockets is used up as combustibles. At this point the rocket having a ζ of 0.50 will begin to decelerate while the one having a ζ of 0.90 will continue to accelerate until the remaining combustibles are used up. It is thus seen that the value of ζ controls the maximum height reached.

The two performance parameters are:

$\sigma T/T_0$ ~ physical properties of the atmosphere called the "atmosphere parameter."

$C_D/C_D{}^*$ ~ aerodynamic properties of the rocket called the "form parameter."

The "atmosphere parameter" for the earth's atmospheric layer will, of course, be the same for all rockets if standard conditions are assumed and its value depends only on the height the rocket has reached above the starting point of the flight. The "form parameter" is determined by the shape of the curve of C_D against B. This curve will be altered chiefly by the geometrical shape of the shell although it is also effected by the change in skin friction coefficient due to the change in Reynolds Number. As long as the rocket belongs to a family that has the same geometrical shape, which implies the same nose shape and the same l/d ratio, that is, the ratio of the length of the shell to the maximum diameter, the "form parameter" can be assumed to remain constant.

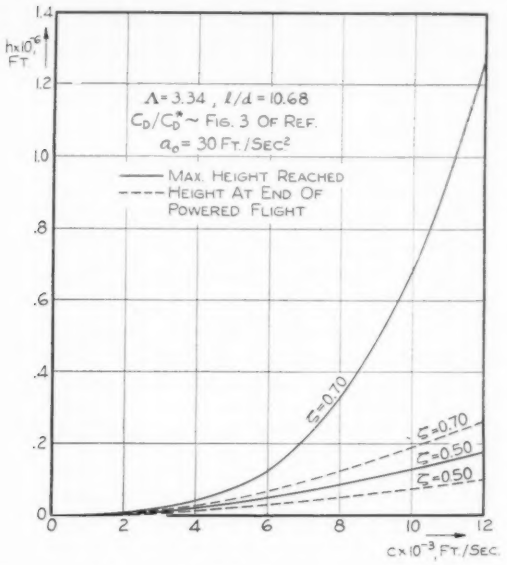


FIG. 4. Height reached in air at the end of powered flight and maximum height reached versus the exhaust velocity, c, for ζ of 0.50 and 0.70.

It is thus seen that the performance curves calculated for a typical rocket will also hold for a whole family of rockets determined by the values of the "factors" and of the "parameters" of the typical rocket and the design of a rocket to meet certain prescribed requirements is greatly simplified. Furthermore, for a good design of rocket form the variation of $C_D/C_D{}^*$, the form parameter, at the same values of B is small. Also, the deviation from standard atmospheric characteristics cannot be very large. Then, in view of the fairly accurate but not exact basic assumption of constant thrust, it is justified to use the same data for these two parameters for all cases. Thus, the performance problem is further simplified and depends only upon the four performance factors a_0/g_0, c, Λ, and ζ.

IV

The use of the results of the analysis developed in the preceding parts of this paper is illustrated in this section by the calculation of the performance of a rocket propelled by successive impulses, *e.g.*, a powder rocket. The performance of the powder rocket can be predicted from the results obtained for an equivalent rocket propelled by constant thrust, provided the powder rocket is acted upon by more than 100 impulses.

In making use of the equivalence existing between the two methods of propulsion it is necessary that the following quantities discussed in Part I and Part III be identical for the two cases: initial acceleration factor, a_0/g_0; exhaust velocity factor, c, for constant thrust and λc for successive impulses; drag-weight factor, Λ; loading factor, ζ, for constant thrust, and ζ_1' for successive impulses; atmosphere parameter $\sigma T/T_0$; form parameter, $C_D/C_D{}^*$; and slenderness ratio l/d.

For the example the following characteristics of the powder rocket are assumed:

POWDER ROCKET

$W_0 = 85$ lbs.
$\zeta_1 = 0.658$.
weight of powder per shot $= 0.108$ lbs.
weight of cartridge $= 0.007$ lbs.
$m = 0.115$ lbs. per shot.
$k = 0.06$.
$\lambda = (l - k) = 0.94$.
$n = 7$.
$N = 518$.
$c = 7000$ ft./sec.
$\lambda c = 6580$ ft./sec.
$\zeta_1' = \zeta_1/\lambda = 0.70$.
$d = 0.75$ ft.
$V = 3.34$.
$C_D/C_D{}^* \sim$ Fig. 3 of reference 6.
$l/d = 10.68$.
$\sigma T/T_0 \sim$ standard atmosphere, starting point —sea level.

EQUIVALENT CONSTANT THRUST ROCKET

$W_0 = 85$ lbs.
$\zeta = 0.70$.
$c = 6580$ ft./sec.
$a_0 = (\zeta_1' n \lambda c/N) - g_0$.
$= 30.0$ ft. per sec.²
$d = 0.75$ ft.
$\Lambda = 3.34$.
$C_D/C_D{}^* \sim$ Fig. 3 of reference 6.
$l/d = 10.68$.
$\sigma T/T_0 \sim$ standard atmosphere, starting point —sea level.

The data for the equivalent rocket are now complete and it is found from Fig. 4 that $H_{max.} = 162{,}000$ feet.

This is the maximum height reached by the rocket assuming that the acceleration of gravity does not vary with height. This assumption was shown in the preceding section to be practically valid for maximum heights up to about 800,000 feet.

Since the sounding rocket at the end of powered flight does not reach heights at which the acceleration of gravity is appreciably decreased, the heights calculated by Malina and Smith[6] can be used. In Fig. 4 the height at the end of powered flight is plotted against the exhaust velocity c for $\zeta = 0.70$ and 0.50 for flight with air resistance. If the height at the end of powered flight is subtracted from the maximum height reached, the coasting height is obtained. This height may be perceptibly affected by the decreasing acceleration of gravity. Using Eq. (24) the corrected coasting height can be calculated. For a sounding rocket propelled by constant thrust of the same dimensions as above but with an exhaust velocity of 12,000 ft. per sec. it is found from Fig. 4 that

$$H_{max._0} = 1{,}270{,}000 \text{ feet}$$

From Fig. 4

$$H_P = 265{,}000 \text{ feet}$$

so that

$$H_{C_0} = H_{max._0} - H_P = 1{,}005{,}000 \text{ feet}$$

Using Eq. (24) the corrected coasting height is

$$H_C = 1{,}005{,}000\left[1 + \frac{1{,}005{,}000}{2.098 \times 10^8}\right] = 1{,}010{,}000 \text{ feet}$$

So that the maximum height with the coasting height corrected for decreasing acceleration of gravity is

$H_{max._0} = H_P + H_C = 265{,}000 + 1{,}010{,}000 =$ 1,275,000 feet

Conclusion

This study shows that a sounding rocket propelled by successive impulses can theoretically reach heights of much use to those interested in obtaining data on the structure of the atmosphere and extra-terrestrial phenomena if a propelling unit gives an exhaust velocity of 7000 ft. per sec. or more.

The possibility of obtaining such exhaust velocities depends upon two factors: first, the ability of the motor to transform efficiently the heat energy of the fuel into kinetic energy of the exhaust gases, and, second, the amount of heat energy that can be liberated from the fuel. In an actual motor which burns its fuel at constant volume by igniting a powder charge in the combustion chamber the ratio of the chamber pressure to the outlet pressure drops from a maximum at the beginning of the expansion to zero at the end of the process. It is not possible to design a nozzle that will expand the products of combustion smoothly during the whole process. Therefore, the attainable efficiency must be less than that of a corresponding "constant pressure" motor which has a mixture of combustibles, *e.g.*, gasoline and liquid oxygen, fed continuously into the combustion chamber at a constant pressure equal to the maximum pressure of the "constant volume" motor. However, very high maximum chamber pressures (up to 60,000 lbs. per sq. in. can be developed in a motor using constant volume burning, while the chamber pressure of a motor using constant pressure burning is limited to much lower pressures by the difficulty of feeding the combustibles. Therefore, the efficiency that can be obtained from motors using either of these processes should not be very different. As to the heat that can be liberated per unit mass of fuel, the present fuel, such as nitrocellulose powder for a constant volume motor, is much lower than the liquid combustibles such as gasoline and oxygen for a constant pressure motor.

These considerations indicate that the attainable exhaust velocity of a "constant volume" motor for propulsion by successive impulses will probably be lower than that of a "constant pressure" motor for supplying a continuous thrust. This is the reason why many experimenters abandoned the "constant volume" motor and turned to the "constant pressure" motor, the so-called liquid propellant motor. Theoretically, this defect of the "constant volume" motor can be compensated if a small total number of impulses (cf. Fig. 3) is used. However, the use of few impulses is of doubtful practical value because the resulting extreme accelerations will be harmful to instruments carried and will necessitate a heavier construction of the rocket.

However, even with the lower exhaust velocities of the "constant volume" motor it is shown by the analysis in this paper that with the exhaust velocity of 7000 ft. per sec. obtained experimentally by R. H. Goddard[1] it should be possible to build a powder rocket capable of rising above 100,000 feet. Thus it seems to the authors that a rocket propelled by successive impulses has useful possibilities and further experimental work is justified.

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Letter to the Editor

November 17, 1938

Dear Sir:

In a letter published in the July, 1938 issue of the Journal, Lieut. Hatcher shows how the distribution of shear stress around the perimeter of a box spar can be determined without resort to the principle of minimum strain energy. In closing his letter he remarks that his procedure constitutes the solution of a statically indeterminate system by statics alone, and leaves this alleged paradox for the next correspondent.

The explanation of the paradox is very simple: *i.e.*, that Lieut. Hatcher's procedure is not based wholly on the principle of equilibrium, but as indicated by his Eq. (1), depends also on the assumption of planar distribution of normal stress over the cross-section. It is, therefore, no more an example of a solution by statics alone, than the analysis of a continuous beam with the aid of the equation of three moments.

Alfred S. Niles
Stanford University

The Application of the Harvard Radio Meteorograph to a Study of Icing Conditions

KARL O. LANGE, *Blue Hill Meteorological Observatory, Harvard University*

Presented at the Meteorology Session, Sixth Annual Meeting, I. Ae. S. January 25, 1938

SUMMARY

Routine radio soundings since December, 1936, have yielded cases in which ice formation greatly affected the ascensional rate of the balloons. In several instances they were forced into a rapid descent of several thousand feet before the ice melted off. From the changes of the rate of ascension, the amount of ice formation can be computed, *i.e.*, radio soundings indicate the existence and amount of icing in the atmosphere.

Present samples of such radio soundings indicate the formation of an amount of ice of the order of magnitude of one kilogram. It formed suddenly and occurred in layers of a steep temperature lapse rate at temperatures slightly above the freezing point and at relative humidities of less than 100 percent. Rapid formation of large quantities of ice near the temperature of the freezing point can be explained only if the way in which the heat of fusion is extracted can be determined. The radio meteorograph records show that the air was not saturated, allowing rapid evaporation of part of the cloud or rain drops after they hit the aircraft. The amount of heat absorbed by this process is sufficient to change considerable amounts of liquid water into ice in a relatively short time. The observational material presented in this paper indicates that relative humidities of less than 100 percent are a prerequisite for dangerous ice formation.

Blue Hill Observatory proposes to conduct a systematic study of the mechanics of ice formation by means of successive radio soundings on days when the regular early morning ascents show icing and by expansion of the rime studies on Mount Washington.

THE HARVARD RADIO METEOROGRAPH

THE Harvard radio meteorograph, ground receiver and recorder, and calibration apparatus were developed during the last three years by the Blue Hill Meteorological Observatory. The equipment has previously been described in detail.[1,2,3,4,5]

The Harvard radio meteorograph, Type F, sends observations on a constant frequency of 68 megacycles. The ground equipment automatically receives and records the signals in the form of curves of temperature, pressure, and humidity *versus* time. The latest type (Figs. 1 and 2) permits transmission of the meteorological observations with a possible accuracy of about 2 mb. and 0.2°C.

ROUTINE SOUNDINGS

In December, 1936, the Harvard radio meteorograph had reached a state of development which permitted the inauguration of a program of routine soundings. The many experimental soundings made prior to that date indicated that the instrument gave reliable data on upper air conditions. During 1937 approximately

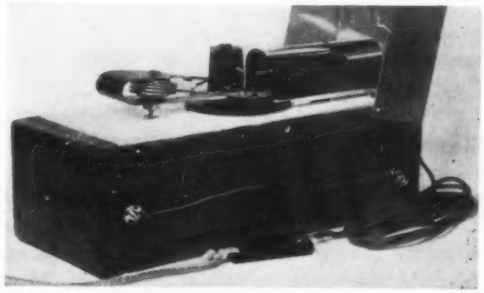

FIG. 1. The Harvard radio meteorograph. The outer sun shield is folded back to show the meteorograph unit with aneroid, hair hygrometer, and bimetal thermometer, and the contact mechanism.

Fig. 2. The 5 meter transmitter of the radio meteorograph. The balsa wood box is open to show the one tube transmitter and A and B batteries.

120 routine radio soundings were conducted by the Blue Hill Meteorological Observatory, the Massachusetts Institute of Technology, and the United States Weather Bureau. Many of these soundings were carried out simultaneously with the government's aerological airplane ascensions. Comparisons of the upper air data obtained by the two methods showed the radio meteorograph to be reliable and accurate.[6,7]

Fig. 3 shows the record of one of these soundings as it is produced by the recorder on the ground while the sounding is in progress. The sets of marks are automatically printed by the recorder, the interconnecting lines are drawn in by hand. The straight line stretching horizontally through the lower part of the record

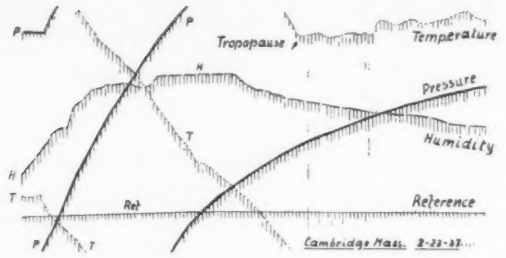

FIG. 3. Record of a routine sounding into the stratosphere.

represents the signals of the reference stylus. It indicates that the clock of the radio meteorograph was adjusted very accurately to a 30 sec. revolution. During the entire ascension, no alteration of the clock speed is noticeable.

The pressure curve starts in the upper left-hand corner of the record. While the meteorograph operates on the ground, the pressure is constant. Then, after launching, the pressure curve slopes upward, leaving the paper. Simultaneously it reappears at the lower edge of the paper, crosses the total width of the paper, and reappears for the second time at the lower edge. The shape of the pressure curve corresponds to the logarithmic relation between pressure and height, indicating that the balloons rise at a constant speed.

The humidity curve does not show any impressive variations, but two points are noteworthy. First, the indicated humidity varies considerably just before the launching. This is due to the great lag of the hair hygrometer which had just been taken outside from a dry, heated room. The launching should have been delayed to allow the hygrometer to adjust itself. Similar faulty humidity measurements must be expected during ascensions whenever quick changes of humidity take place. Second, shortly after the humidity curve crosses the temperature curve, there is a thick layer of 100 percent humidity, indicating the presence of clouds. These clouds do not affect the rate of ascension, *i.e.*, the balloons are not weighed down by water or ice deposit.

The temperature curve begins in the lower left-hand corner. After launching, it drops rapidly, interrupted by a number of insignificant inversions, until the stratosphere is reached. From that point on, the temperature remains nearly constant.

The sounding lasted a little over one hour, and was terminated by fading out of the radio signals.

Observation of Icing

Figs. 4 and 5 show the meteorograph records on two days when icing occurred. Of special interest are the pressure curves which roughly indicate the heights. Fig. 4 shows that the balloon at first rose normally. Then, within a 30 sec. interval, the ascension was checked and a descending motion started. From this point on several pressure contacts were not recorded,

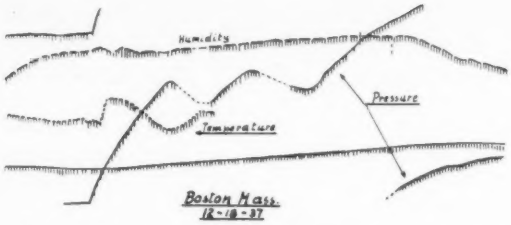

FIG. 4. Actual record of the recorder of the radio meteorograph, showing icing conditions on December 18, 1937.

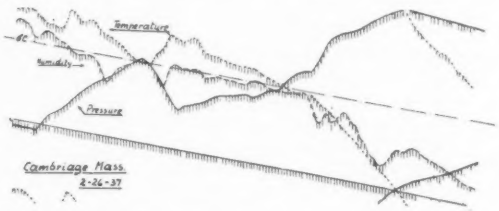

FIG. 5. Actual record of the recorder of the radio meteorograph, showing icing conditions on February 26, 1937.

probably on account of an ice deposit on the pressure contact arm. They can be reconstructed, however, from the temperature trace. They reappeared when the ice melted and a new ascent began. Unfortunately the temperature contacts failed from this time on. The exact temperature conditions under which a second change from ascent to descent took place when the balloon made its second attempt to go through the icing layer are therefore not established. Fig. 5 also shows a normal ascent to begin with. After a while, the balloons suddenly reversed direction, descending somewhat faster than they had risen. The curves of temperature and humidity show a corresponding reverse, producing a nearly symmetric picture. After the ice melted off, the balloons rose again, and this time passed the icing layer with less significant changes of the ascensional rate.

Variations of the ascensional rate of balloons may be due to vertical currents in the free atmosphere. The author believes that this possibility can be excluded from consideration in the two cases presented in this paper, because the general state of stability indicated by the fog, stratus clouds, and the temperature lapse rates should make extended down currents of 5 meters per sec. impossible.

The two records in Figs. 4 and 5 can give only a qualitative picture of the conditions. Fig. 6 shows the quantitative data as they were obtained by the evaluation of the original records by means of their calibration charts and by computation of the altitudes.

Fig. 6 shows relative humidities and temperatures of significant levels plotted against dynamic meters (dynamic meter = $10 \times$ meters/g). The ascensional rates between two significant levels were determined from the height differences and the time intervals between significant levels.

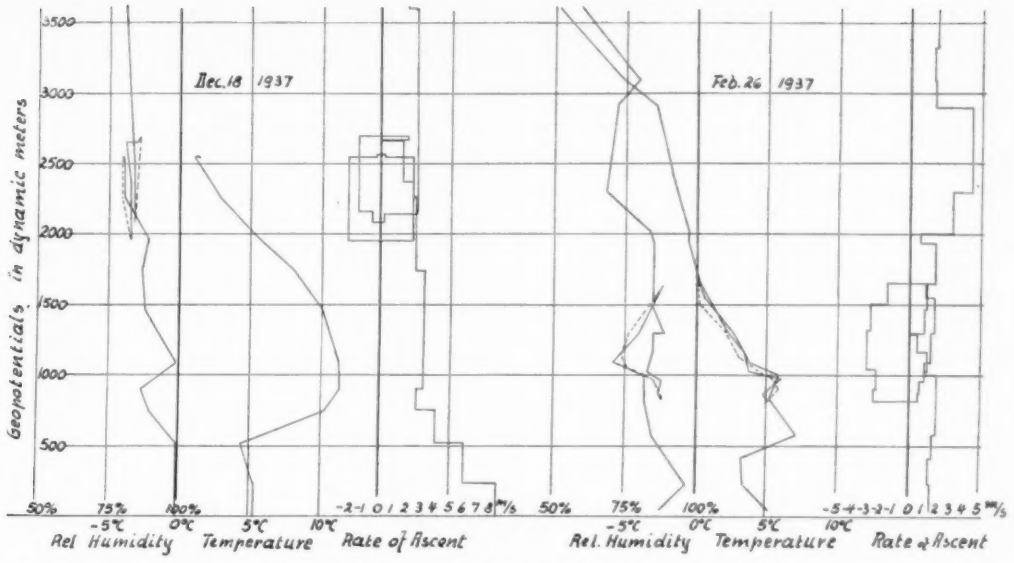

FIG. 6. Temperatures, relative humidities, ascensional rates, and heights as recorded by radio meteorographs on December 18 and February 26, 1937.

On December 18, 1937, at 6 a.m. ground conditions were: calm, moderate fog, 10/10 stratus clouds, light rain. The radio-meteorograph data (Fig. 6) located the top of the fog at 500 meters. The stratus clouds began at about 900 meters; their top was at 4300 meters. There was a remarkable inversion over the fog layer.

On this day a radio meteorograph was used which weighed 420 gms., the single balloon weighed 356 gms., parachute and string 90 gms., and a free lift of 370 gms. was provided. In other words the total lift was 1236 gms. Under the assumption that commercial hydrogen at surface conditions furnishes a lift of about 1 kg. per cu. meter, the content of the balloon must have been about 1250 liters. This means the diameter of the balloon was about 134 cm. The corresponding cross-section $F = 1.41$ sq. meters. Drag coefficients of balloons of this size at the conventional ascensional speeds have been experimentally determined. The Reynolds Number of a 134 cm. balloon near the ground is about 50,000 when the ascensional rate is 0.5 meters per sec. It is 300,000 for an ascensional rate of 3 meters per sec. The range of Reynolds Numbers from 120,000 to 250,000 represents a critical region where the mean values of drag coefficients of such balloons have been found to fall off nearly 50 percent. However, drag coefficients of 0.48 to 0.28 have been measured on both sides of the critical region. For the following computation, a low value $c = 0.30$ was employed. It is, however, quite possible that a higher value would have been justified which would make the amounts of ice larger than as computed in the following paragraphs.

The free lift of $L = 370$ gms. accelerates the balloon until the drag equals the lift, *i.e.*, almost immediately after launching, the balloon assumes a constant rate of rise v_z. It is well established that under ordinary circumstances this rate remains nearly constant up to great heights in spite of the many factors that tend to change it.

The constant ascensional rate may therefore simply be determined for surface conditions (mass density of air $\rho = 0.125$). It is:

$$L = c \cdot (\rho/2) \cdot F \cdot v_z^2$$

For the balloon of December 18, 1937, under the assumption that $c = 0.30$

$$v_z = \sqrt{\frac{0.370 \times 2}{1.41 \times 0.125 \times 0.30}} = 3.7 \text{ meters per sec.}$$

Fig. 6 shows that the observed ascensional rate, though it was much larger right after launching, adjusted itself after a few minutes to 3 meters per sec. and 2.5 meters per sec., decreasing slightly with altitude. This must mean that part of the original free lift was compensated by rain water clinging to the balloon. A rate of rise of 3 meters per sec. is obtained from a free lift of 245 gms. and 2.5 meters per sec. from 170 gms. Hence, the water ballast must have amounted to 370 gms. minus these amounts, *i.e.*, 125 to 200 gms. At an altitude of 2600 meters the ascensional rate changed to 0.3 meters per sec., then to a descent of 0.3 meters per sec., then to a descent of 2.2 meters per sec., each step requiring 30 sec. 170 gms. of ballast were needed to check the ascent. Another 130 gms. were required to cause a descent of 2.2 meters per sec. The total is 300 gms. Since it may safely be assumed that the balloon was as wet as it would get before reaching this altitude, this deposit of 300 gms. must have been ice. It formed within one minute and a half. The tem-

perature was still 1°C. above the freezing point, and the relative humidity was registered as 80 percent. The hair hygrometer is known to be an imperfect instrument and the fact that the relative humidity in fog or clouds need not be 100 percent is not generally recognized. The author believes, however, that there can be no doubt in this case that the relative humidities are less than 100 percent because the hygrometer had clearly measured 100 percent up to 500 meters and at 1100 meters. Small variations of humidity between 80 and 90 percent are well recorded and even at 4300 meters, where the temperature is likely to have been much lower, affecting adversely the efficiency of the hygrometer, it registers a drop of humidity from 80 to 50 percent. During the two ascents and descents of the balloon, enough time elapsed to eliminate lag. The lapse rate is steeper than condensation adiabatic, which would be unlikely at 100 percent humidity.

The ice melted at 2000 meters where the temperature was 5°C. A second ice deposit took place about 500 feet higher than the first one. No temperature measurement is available, but it is likely that the temperature was slightly below the freezing point. Other soundings too show ice formation at minus temperatures.

Curves of the radio sounding of February 26, 1937, are shown on the right-hand side of Fig. 6. Surface conditions were: rain, wind velocity 8 m.p.h. The aerological data indicate a turbulence zone of 200 meters with an adiabatic lapse rate with increasing humidities. Above, there was an inversion followed by a steep lapse rate. Between 800 and 1000 meters another inversion existed, above which there was a thin layer with an extraordinary lapse rate. A sharp drop of humidity was recorded. One is tempted to explain the sudden drop of temperature as an instrumental error, namely a wet bulb effect of the thermometer emerging from the clouds. However, this region was covered by the radio meteorograph three times, each time recording essentially the same conditions. A wet bulb effect would not occur during the descent from cold dry into warm moist air. There are other cloud tops at 2000 meters and at 3200 meters.

On this day a radio meteorograph of 450 gms. plus about 50 gms. of strings was sent aloft on two balloons, one with 900 gms. and one with 600 gms. of free lift. The total free lift was therefore 1000 gms. It is not possible to establish with any degree of accuracy a theoretical rate of ascension for a team of balloons because they constantly shift their positions relative to one another and hence their drag varies. The sounding of February 26, 1937, presented a rate of climb of 3 meters per sec. after the balloon emerged from the clouds at 2000 meters. Between 2300 and 2900 meters the speed was 4.3 meters per sec. In this cloudless layer the balloons must have shed all of their water and, moreover, they must have assumed a position of small air resistance. A number of other radio soundings with two balloons of equal weight and lift proportions furnished ascensional rates of 2.5 to 3.5 meters per sec. Assuming that 3.0 meters per sec. is the basic rate of rise of the balloons with their given free lift of 1000 gms., then water deposits must have decreased this lift to $(1.9^2:3.0^2)\cdot 1000 = 400$ gms. during the first part of the ascension. At 1650 meters the ascent was checked, and it reversed into a descent which finally reached the rate of 3 meters per sec. The corresponding total ice deposit is $400 + 1000 = 1400$ gms. The fastest rate of ice formation occurred at 1500 meters with about 440 gms. in 60 sec. At both altitudes humidities were definitely less than 100 percent and the temperatures were +0.1°C. and +1.0°C.

In both cases described above, ice formation occurred at temperatures above the freezing point and at relative humidities of between 80 and 90 percent. The ice formed on one balloon at a maximum rate of 3.3 gms. per sec. and on the two balloons at a maximum rate of 7.3 gms. per sec.

In order to explain the ice formation, it is necessary to establish, first, that the balloons could have encountered at least the equivalent amount of water and, second, that the heat of fusion was taken out of this water.

No measurements were made on the intensity of the rain at the altitudes where icing occurred nor on the number and size of cloud droplets that may have struck the balloons.

However, general measurements of the amount of liquid water in clouds are available. According to an as yet unpublished paper of H. G. Houghton, clouds and fog contain from 0.01 to 4.5 gms. per cu. meter. These figures were obtained by actual measurements and 4.5 gms. per cu. meter is probably not the absolute maximum that could be found in clouds which are producing rain. While icing occurred, the balloons moved with a vertical speed of the order of magnitude of 2 meters per sec., *i.e.*, with their cross-section of about 1.5 sq. meters they traversed a volume of approximately 3 cu. meters every second. Under the assumption that all of the available droplets in 3 cu. meters were deposited on the balloon and that the clouds contain the maximum measured water content of 4.5 gms. per cu. meter, about 13 gms. of water would have been collected by each balloon each second. The icing measurements show that about one third of this amount deposited on the balloons as ice.

In order to change the water into ice, the heat of fusion of 80 calories for each gram of water has to be liberated. It is unlikely but not inconceivable that the temperature of the cloud droplets was substantially lower than the air temperature which was measured to be above the freezing point. Assuming that there were cloud drops or perhaps raindrops subcooled to −5°C., they would assume a stable condition on striking the balloons, *i.e.*, they would form a freezing mixture at 0°C. Calorimetric computations show that approxi-

mately $^1/_{16}$ of the water deposited must be frozen in order to raise the temperature of the mixture of ice and water to 0°C. Hence, if ice formation is to be explained by the presence of subcooled water alone, it is necessary not only to assume an improbable amount of subcooling, but also that there is at least five times as much water in clouds as has ever been measured.

It is more likely that the cloud drops have approximately the same temperature as the air. They strike the balloons and are carried up, being ventilated with the speed of the balloon. The surrounding air was found to have less than 100 percent relative humidity. Consequently evaporation must take place. Approximately 600 calories are needed to evaporate one gram of water. This large cooling effect tends to lower the temperature on the surface of the balloons to the freezing point, and quickly freezes large quantities of the rest of the water. W. Bleeker,[8] has pointed out that similar effects may be the cause for the rapid formation on aircraft of large quantities of ice in a very short time.

The few available cases of icing measurements with radiometeorographs are not sufficient to explain with certainty and accuracy icing and its correlation to other meteorological factors. These soundings were routine soundings—not especially made for a study of icing—and some factors, which are important for icing investigation, were not measured and had to be estimated. The numerical results obtained in this paper should, therefore, be considered only in their order of magnitude. The Blue Hill Meteorological Observatory intends to conduct a series of systematic soundings through icing layers when they are known to exist. At the same time measurements on ice deposits and cloud conditions on Mount Washington will be continued to supplement the information gained from the free atmosphere.

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Book Reviews

Air Navigation, by P. V. H. WEEMES; McGraw Hill Book Company Inc., New York, Second edition, 1938; 587 pages, $5.00.

Martin's Air Navigation, by C. W. MARTIN; The Eversley Press, Ltd., Third edition, 1938; 368 pages; 25s.

The art of navigating the air is rapidly developing into an exact science, and during the past ten years specialists in many countries have devoted their attention to this important part of every pilot's training. As a result, there exist several excellent books on Aerial Navigation. The present review deals with new and revised editions of two standard textbooks on the subject. Commander Weems' book is in its second edition; there is also a British Empire edition of the work. Mr. Martin's book is in its third edition.

In this country, Commander Weems has made notable contributions to aerial navigation. Each country, however, has somewhat different regulations and requirements. In England, for instance, a 2nd Class Air Navigator's License has become an essential qualification for a successful career in civil aviation, and may be considered as the matriculation of the air. Mr. Martin has been an instructor in the Imperial School of Air Navigation in London and has used his book as a text in this as well as in other schools.

The Weems book is the standard work in this country and the present edition contains much information not available in the 1931 edition. An "Outline of Meteorology," prepared by Dr. Sverre Petterssen is particularly excellent. In addition, the short method of "Star Altitude Curves" has been completely recomputed and a new technique for its use developed. Celestial navigation methods are covered in detail. Mechanical computers, which have largely replaced the dead-reckoning tables formerly in use, are described and illustrated.

Mr. Martin's book has been written to serve as a textbook for those who are preparing for the examination of the Air Ministry for a 2nd Class Navigator's License. The contents follow closely the Air Ministry Syllabus. The greatest change in this over previous editions is the chapters on Meteorology and Air Regulation. These have been completely rewritten. A glossary of terms at the beginning of the chapter on Meteorology should be especially helpful. These terms are, for the most part, those used in this country as well as in England. Notable exceptions are the definitions of mist and drizzle, which in this country correspond approximately to thin fog and mist, respectively.

Both books have definite fields; the Martin book is particularly suitable for English students while the Weems book, being the more comprehensive, is suitable for a more detailed study of the subject.

Proposed Method for the Design of Bottom Plating for Flying Boat Hulls and Seaplane Floats[1]

SYDNEY D. BERMAN, *Civil Aeronautics Authority*

(Received August 1, 1938)

THE lack of complete data for designing the bottom plating of flying boat hulls and floats prompted the author to investigate the subject of stresses in the plating due to the normal pressures incurred while taking off or landing. In this undertaking, use was made of an approximate method of determining the stresses in thin plates given by Timoshenko.[2] Since the dimensional requirements for adequate strength obtained by the author's application of Timoshenko's method are in close agreement with successful practice, the resulting design information is presented herewith in the hope that the designer will find it useful.

The notations used in the mathematical analysis are:

l = distance between stringers
D = flexural rigidity
E = modulus of elasticity
t = skin thickness
μ = Poisson's Ratio
δ = deflection at the middle
δ_0 = deflection produced by lateral loads only
y = deflection at distance x
p = unit pressure
λ = extension of the strip
T = tension in the plate
f_t = stress due to tension only
f_p = stress due to bending only

It is assumed that the portion of the plating included between two adjacent (parallel) longitudinal stringers is subjected to a uniform normal pressure. Since the length of the panel thus considered is large in comparison with its breadth, the deflection surface is nearly a cylindrical one, and the differential equation for the deflection curve of a strip of unit width, whose initial length, l, is the distance between stringers, is

$$Dd^2y/dx^2 = -M$$

where the flexural rigidity, D, is defined by

$$D = \frac{Et^3}{12(1-\mu^2)}$$

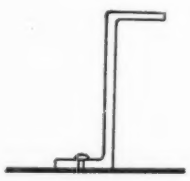

FIG. 1.

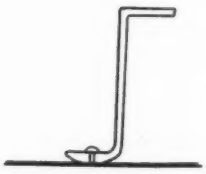

FIG. 2.

It is clear that the value of the bending moment M at any distance x from the origin depends upon the edge conditions; *i.e.*, the conditions of edge restraint which will influence the slope of the deflection surface of the plate at any point. The amount of the restraint will depend primarily upon the rigidity of the stringer and the shape of the portion of the surface of the latter to which the plating is fastened. Timoshenko analyzed the problem for two extreme conditions in which: (a) the edges were simply-supported and thus free to rotate in bending, and (b) the edges were clamped. It is evident, therefore, that the determination of the true stresses in any practical case must be based upon some intermediate condition.

Fig. 1 represents a plate-stringer combination which conforms approximately to condition (b) of the last paragraph; whereas a type of stringer which allows the assumption of approximately free edge conditions is shown in Fig. 2. Calculations have been made for the two extreme conditions of edge restraint and the design values taken as the mean between them.

CASE A—SIMPLY SUPPORTED PLATE

The equation of the deflection curve is assumed to be

$$y = \delta \sin(\pi x/l) \tag{1}$$

since y will be a maximum at $x = {}^1/_2$ and zero at $x = 0$ or $x = l$. In this case Timoshenko shows that the deflection δ at the middle may also be expressed by the auxiliary relation

$$\delta = \delta_0/(1+\alpha) \tag{2}$$

where

$$\delta_0 = 5pl^4/384D \tag{3}$$

is the deflection which would be produced by the bending only, and

$$\alpha = Tl^2/\pi^2 D \tag{4}$$

[1] The opinions expressed herein by the author are not intended to be construed as those of the Civil Aeronautics Authority.

[2] Timoshenko, S., *Strength of Materials*, Part II, Chapter III.

The extension of the strip is given approximately by

$$\lambda = \frac{1}{2}\int_0^l \left(\frac{dy}{dx}\right)^2 dx; \tag{5}$$

or, from Eqs. (1), (2), and (5),

$$\lambda = (\pi^2/4l)\delta_0^2/(1 + \alpha)^2 \tag{6}$$

If the lateral contraction of the strip, due to bending, is neglected one may also write

$$\lambda = \frac{Tl^2(1 - \mu^2)}{Et} = \frac{\pi^2\alpha t^2}{12l} \tag{7}$$

Therefore, upon equating Eqs. (6) and (7) one obtains

$$\alpha(1 + \alpha)^2 = 3\delta_0^2/t^2 \tag{8}$$

For the purpose of simplifying the numerical solution for α, write $r = (1 + \alpha)$; then Eq. (8) becomes

$$r^3 - r^2 = 3\delta_0^2/t^2 \tag{8a}$$

from which r, and then α, can be calculated, since the right-hand side of Eq. (8a) will be known.

In order to determine the tension, T, in the plate, first calculate the deflection δ_0 from Eq. (3) and then x and α from Eq. (8a). The stress due to tension only is

$$f_t = T/t = \pi^2\alpha D/l^2t \tag{9}$$

For free edges the maximum bending stress is at the center and is equal to

$$f_b = \frac{3}{4}(pl^2/t^2)\psi_1(u) \tag{10}$$

where

$$u = (\pi/2)\sqrt{\alpha}$$

and

$$\psi_1(u) = 2(\cosh u - 1)/u^2 \cosh u \tag{11}$$

The total tensile stress at the center of the plate is equal to the sum of the stresses given by Eqs. (9) and (10); whereas the edge stress in this case is simply that due to Eq. (9) only.

Case B—Clamped Edges

The equation of the deflection curve in this case is taken as

$$y = (\delta/2)[1 - \cos(2\pi x/l)] \tag{12}$$

where

$$\delta = \delta_0/(1 + \alpha/4) \tag{13}$$

and δ_0 has the value

$$\delta_0 = pl^4/384D \tag{14}$$

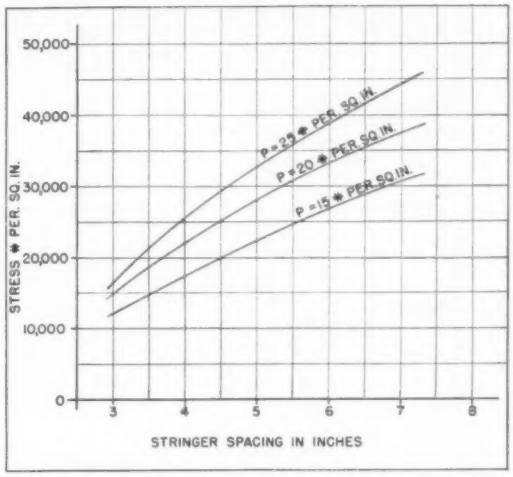

FIG. 3. Stress on Bottom Plating 0.064 in. thick with Variable Pressure Loading and Stringer Spacing.

From Eqs. (1), (5), (7), and (13) one obtains

$$\alpha(1 + \alpha/4)^2 = 3\delta_0^2/t^2 \tag{15}$$

or, by letting $r = (1 + \alpha/4)$

$$r^3 - r^2 = \frac{3}{4}\delta_0^2/t^2 \tag{15a}$$

from which r, and then α, may be calculated. The stress due to the tension, T, is given by Eq. (9), using the value of α from Eq. (15).

In the case of clamped edges the bending stresses are

$$(f_b)_{x=0} = (f_b)_{x=l} = (pl^2/2t^2)\psi_2(u) \text{ at the edges} \tag{16}$$

and

$$(f_b)_{x=l/2} = (pl^2/4t^2)\psi_3(u) \text{ at the center} \tag{17}$$

where

$$u = (\pi/2)\sqrt{\alpha}, \text{ and}$$
$$\psi_2(u) = (u - \tanh u)/(\tfrac{1}{3}u^2 \tanh u)$$
$$\psi_3(u) = (6/u^2)(\sinh u - u)/\sinh u$$

The total tensile stress at the edge is the sum of Eqs. (19) and (16), and at the center the sum of Eqs. (9) and (17).

Values for the design of the bottom plating were calculated for skin thickness of 0.032, 0.040, 0.051, and 0.064 ins. with a variation of loading of 25 lbs. per sq.in., 20 lbs. per sq.in., and 15 lbs. per sq.in. for stringer spacings of 3 in., 4 in., 5 in., 6 in., and 7 in. Since space is limited, calculations are given here only for a loading of 25 lbs. per sq.in. skin thickness of 0.064 in.; the method for the other skin thicknesses is similar.

From the following calculations it will be seen that in Case A the stresses at the edges are high, whereas in Case B they are low. The designer should take ad-

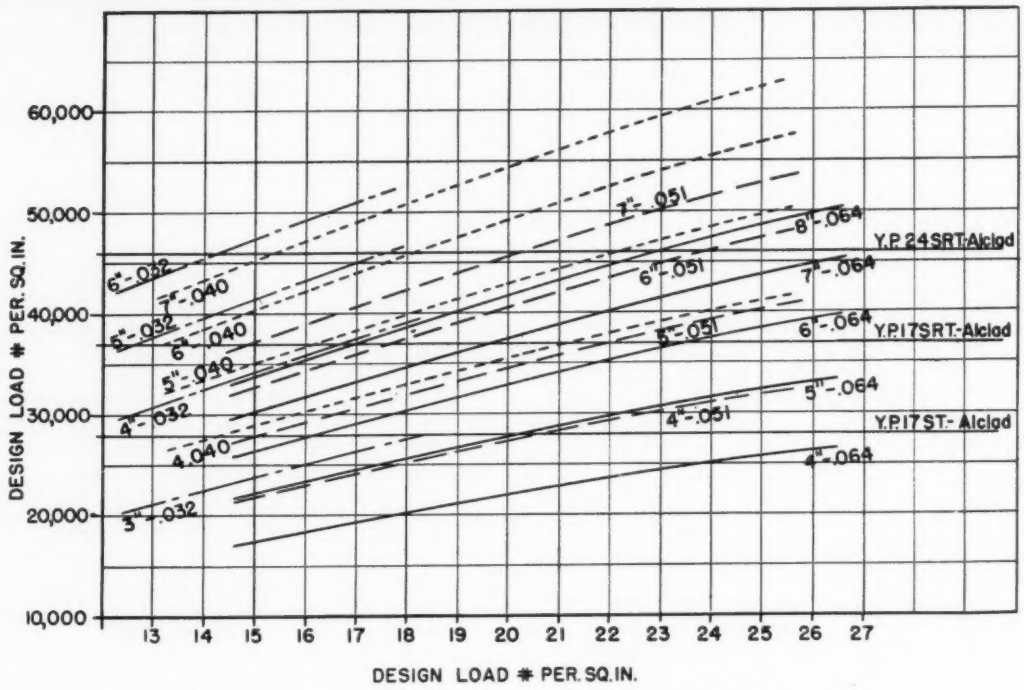

FIG. 4. The ordinate refers to stress in the plating; the abscissa refers to the water load.

TABLE 1

Modulus of Elasticity, E = 10,300,000 Lbs. per Sq.In.
Poisson's Ratio, $\mu = 0.3$

Skin Thickness t	0.032	0.040	0.051	0.064
D	31.2	61.0	125	247

TABLE 2

Case A—Skin Thickness 0.064 In.—Loading 25 Lbs. per Sq.In.

Stringer Spacing	3 In.	4 In.	5 In.	6 In.	7 In.
pl^4/D	8.2	25.9	63.3	131	243
δ_0	0.1065	0.337	0.825	1.705	3.16
$x^3 - x^2$	8.3	83	497	2120	7320
x	2.4	4.7	8.26	13.2	19.7
α	1.4	3.7	7.26	12.2	18.7
u	1.86	3.02	4.24	5.5	6.82
ψ_1	0.39	0.21	0.11	0.065	0.045
$M_{max.}$	10.95	10.5	8.57	7.3	6.9
f_b	16000	15400	12570	10700	10100
f_t	5950	8850	11100	12950	14600
Total Stress at Center Line	21950	24250	23670	23650	24700
Total Stress at Support	5950	8850	11100	12950	14600

TABLE 3

Case B—Skin Thickness 0.064 In.—Loading 25 Lbs. per Sq.In.

Stringer Spacing	3 In.	4 In.	5 In.	6 In.	7 In.
δ_0	0.0213	0.0674	0.165	0.341	0.632
$x^3 - x^2$	0.083	0.83	4.98	21.3	73.2
x	1.07	1.42	2.1	3.1	4.55
α	0.28	1.68	4.4	8.4	14.2
u	0.835	2.03	3.31	4.56	5.94
ψ_2	0.945	0.806	0.630	0.511	0.420
ψ_3	0.915	0.675	0.415	0.266	0.165
Moment at Support	17.7	26.9	32.8	38.3	42.9
Moment at Center	8.56	11.25	10.8	9.96	8.42
f_b at Support	26000	39400	48000	56100	62900
f_b at Center	12550	16500	15800	14600	12350
f_t	1190	4010	6720	8910	11100
Total Stress at Support	27190	43410	54720	65010	74000
Total Stress at Center	13740	20510	22520	23520	23450

vantage of this fact, and use a type of longitudinal stringer, such as shown in Fig. 2, which will cause only a slight amount of bending at the line of attachment to the plate. Fig. 4 is derived on the supposition that, as stated before, the edge conditions produce stresses

which are the average of the two extreme conditions considered in the foregoing discussion. The final results are those already referred to and shown on the chart in Fig. 4, based on the constants for aluminum alloy given in Table 1.

It should be noted that the *allowable* stress at *ultimate* load should be taken as the *yield point* of the material.

EXAMPLE

The design loading for a particular flying boat at the keel, at the step, is 24 lbs. per sq.in. Assuming the material to be used is 24 SRT Alclad, then Fig. 4 shows that a plate thickness of .051 in., with 6 in. stringer spacing will be satisfactory.

TABLE 4

Average of Case A + Case B—Thickness 0.064 In.—Loading 25 Lbs. per Sq. In.

Stringer Spacing	3 In.	4 In.	5 In.	6 In.	7 In
Total Stress at Support	16570	26130	32910	38980	44300
Total Stress at Center Line	17845	22380	23095	23580	24075

Book Reviews

James Jackson Cabot Professorship Lectures, Norwich University, Northfield, Vermont. **International Organizations and the Control of Aeronautics** by JOHN J. IDE; 37 pages; **The Early History of Air Transportation** by EDWARD P. WARNER, 74 pages; **Technical Development and its Effect on Air Transportation,** by EDWARD P. WARNER, 42 pages. $.50 each or $2.00 for the set of six lectures. The above are now available; three more are in the process of preparation.

The James Jackson Cabot Professorship of Air Traffic Regulation at Norwich University was established by Dr. Godfrey L. Cabot of Boston in memory of his son. J. J. Ide, who for many years has represented the N.A.C.A. in Europe, gave the first of the series in 1934–35. It has been revised and brought up to date in the present pamphlet.

Few persons have any considerable knowledge regarding the extent and functions of the numerous international organizations that have to do with the regulation and control of air traffic. Based on his broad knowledge in this field, Mr. Ide has divided these organizations into three classes: governmental, official, and unofficial. This listing includes organizations which treat Aeronautics incidentally as well as those whose functions are exclusively aeronautical. Brief sketches of twenty-five of these organizations are given. The resulting booklet will be a helpful handbook for those interested in the international aspects of Aeronautics.

Dr. Warner's two lectures (three more are under preparation and will be published as part of the series) are typical examples of his encyclopedic knowledge of Aeronautics. In a comparatively few pages, he traces the history of air transportation in this country and in Europe. With great discrimination, he has culled the essentials from the great mass of miscellaneous efforts which mark the beginning of air transportation. The author's close association with practically all of the pioneers in this field give his opinions of each succeeding event an authoritative character.

In his second lecture, Dr. Warner treats the effects of technical development on air transportation. He has devoted much study to this field in connection with his consulting practice with airplane companies in developing new types of commercial aircraft, particularly the DC-4.

To the best of our knowledge, this represents the most concise presentation on this subject available. Increases in wing loading, N.A.C.A. engine cowling, higher octane fuels, adjustable pitch propellers, retractable landing gears, flaps, and other improvements are analyzed from the standpoint of the cost per ton mile in air transport operation. Six typical transport planes, which have been in use since the inauguration of Air Mail, are considered. Using the DC-3 as the latest type the lecture concludes with the promise of an examination, in the next lecture, of possible further decreases in operating costs.

These lectures are certain to have a great effect on the development of air transport in this country. Great credit is due Dr. Porter H. Adams, President of Norwich University, who has played a prominent part in the advancement of Aeronautics, for his efforts in inaugurating this series.

LESTER D. GARDNER

Air Piloting, by VIRGIL SIMMONS; The Ronald Press Company, New York, 1938. 284 pages; $3.00.

This book is designed to give information which will help Student and other classes of pilots become more proficient, and to enable them to pass examinations admitting them to higher grades. The author graduated from the U. S. Naval Aviation Ground School at the Massachusetts Institute of Technology and he has had wide experience in the U. S. Army and Navy Air Services. He has been flying instructor at various schools including the Boeing School of Aeronautics.

The various chapters cover the range from "Primary Flight Training" to "Flying Instructor Rating." All flight test maneuvers now required for the various pilot certificates and special ratings are analyzed and explained. The courses of instruction leading to the various certificates are described.

The book will serve as an authoritative textbook for use in primary and instrument flying, and will also be useful to pilots who wish to correct faults and attain a greater proficiency in flying. Each step in the progressive development of a pilot is covered by questions and answers which are largely taken from official examinations so that the pilot will know in a general way what to expect when he comes to the final tests.

The illustrations which accompany the text are carefully drawn and selected.

The treatment is necessarily brief on some points, such as radio, instrument flying, and meteorology. The author recommends, particularly with regard to meteorology, that a course in the subject be pursued along with the flight training.

Flight Test Research on the Problem of Vapor Lock

N. F. SCUDDER, *The Glenn L. Martin Company*

Presented at the Meeting of the Los Angeles Branch of the I. Ae. S.
September 30, 1938

Introduction

THE fuel systems of the earliest airplanes were simple in form, usually gravity systems. As aerodynamic requirements made it necessary to enclose all parts within the wings and fuselage, certain complications began to appear. One of these was the occurrence of bubbles of air or fuel vapor in fuel lines complicated by many bends, valves, and fittings or exposed to engine heat. The bubbles caused interruption of flow of fuel giving rise to so-called "air lock" or "vapor lock." To provide dependability, the use of fuel pumps became common. This expedient was sufficient, in general, for many years, until the delivery required of a fuel system and the climbing performance of the airplane had been greatly increased as the result of increases in power and efficiency. Thus a number of troubles have appeared, all related in one way or another to two important characteristics of the fuel: its volatility and its ability to dissolve air. The first of these is well known, but the second is not as commonly recognized.

All phenomena in fuel systems involving the presence of gas or vapor entrained in the fuel are now called "vapor lock." In this sense the title of the present paper is justified, but it is probably true that no fuel system provided with a fuel pump and reasonably protected from engine heat ever fails because of the phenomenon to which the term was originally applied.

The causes of failure of the fuel systems of ultra-high-performance airplanes are numerous. Many of them relate to the design, position, and capacity of fuel pumps and their supply lines and to the action of relief valves. A recent investigation of these factors has been completed by the U. S. Army Air Corps at Wright Field.[1] The investigators there developed a successful method of correcting the troubles in pump operation up to exceptionally high altitudes. The investigation, reported herein, of tests recently conducted by The Glenn L. Martin Company led to the development of a simple device for separating the gas liberated in the fuel system.

Preliminary Observations

Observations were made in the course of extensive flight tests of twin-engine bombardment airplanes manufactured for export, similar to the U. S. Army B-10B airplane, but fitted with Wright GR-1820-G2, G3, and G5 engines. The carburetors used were Stromberg Model NAF-7, a type in which mixture strength control is accomplished by means of bowl suction. Prior to making systematic tests on this subject the phenomenon of vapor lock was observed several times. In mid-summer almost complete loss of engine power occurred frequently during performance climb tests at altitudes of 13,000 ft. and higher, while in winter weather loss of power was experienced only above 20,000 ft. In some cases it was not possible to maintain level flight at 19,000 ft. in an airplane having a service ceiling of 23,000 ft., and it was noted generally that the Cambridge exhaust-gas analyzer showed erratic variation of mixture strength. The fuel pressure gage was known to be responsive to high frequency changes of pressure, but no fluctuations whatever were noted just before or during periods of engine stoppage.

At first, Stanavo 87 octane fuel of Reid Vapor Pressure 7 lbs. was in use. Later in the summer 6 lb. fuel was used. The fuel was delivered from underground storage tanks at 80°F. to 85°F. If the airplane had been allowed to stand in the sun for two or three hours after having been serviced the temperature of the fuel in the top of the tanks reached 95°F. A thermocouple was installed in the fuel line fitting at the carburetor, so placed that the couple was in the center of the stream of fuel. The temperature of the fuel entering the carburetor either on the ground or in flight was found to be never more than 5°F. above that of the fuel leaving the tank. However, neither the tank temperature nor that of the fuel entering the carburetor decreased appreciably during a climb until a high altitude was reached.

For the purpose of making a performance test, early in July, 1937, a tank full of fuel was cooled to 60°F. and during the test it entered the carburetor at 60° to 62°F. Control of mixture strength was indefinite, but the engines did not stop.

The engine-driven pump was the Pesco Model R-600-BE vane-type pump. It was mounted several inches below the tank outlet, aft of the firewall in the engine nacelle and was driven by a flexible shaft at engine crankshaft speed. This type of pump, it should be pointed out, pumps fuel in a quantity dependent only upon the speed at which it is driven. The quantity delivered by one pump is more than twice

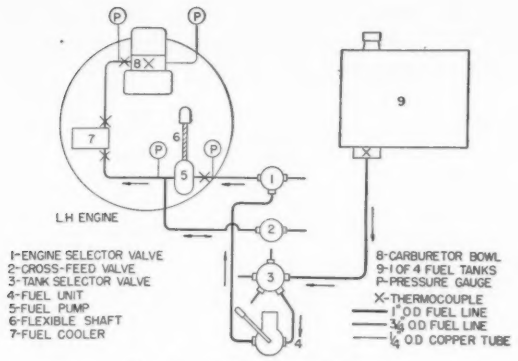

FIG. 1. Fuel system diagram.

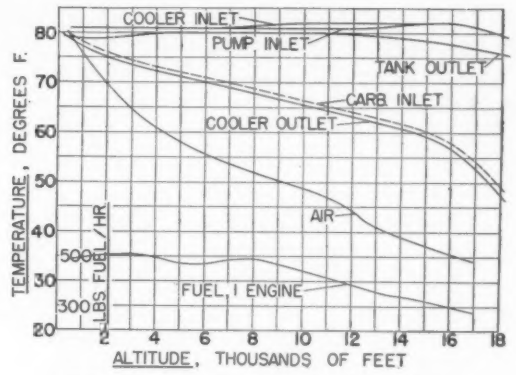

FIG. 2. Temperature survey in fuel system.

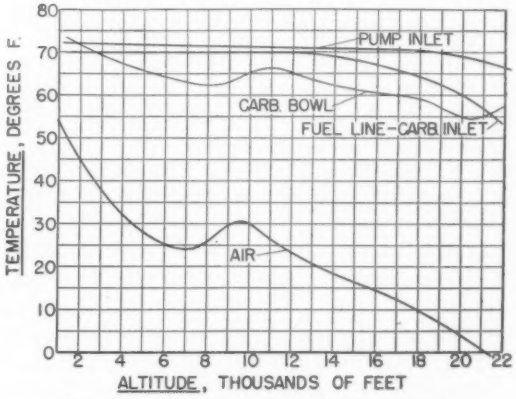

FIG. 3. Temperatures, including float bowl.

the amount required at any particular speed and the difference between pump delivery and the usual single engine requirement flows back into the pump inlet by means of a bypass valve. The action of a relief valve has been found in the present tests, and in the Army tests mentioned earlier, to be undesirable, but since no loss of fuel pressure occurred, attention was not directed to the pump as the cause of the trouble.

SURVEY OF FUEL SYSTEM FUNCTIONING

The apparent improvement in operation with precooled fuel made it seem worthwhile to make a pressure and temperature survey of the fuel system, and to test the action of fuel coolers. Fuel temperature was considered to be an important factor.

Fuel coolers were built into the system between the fuel pump and the carburetor and six thermocouples were installed in the fuel stream at the following points: tank outlet, fuel pump inlet, cooler inlet (which for all practical purposes also represented pump outlet), cooler outlet, carburetor inlet, and carburetor bowl. Fuel pressures were measured at the pump inlet, pump outlet, carburetor inlet, and above the fuel in the carburetor bowl. The points where temperatures and pressures were read are shown in Fig. 1.

The results of the temperature measurements during a normal climb are shown in Fig. 2.

Fig. 3 shows the carburetor bowl temperature for a similar installation during a similar climb. The thermocouple in the latter case was inserted through an opening in the top of the carburetor and completely immersed in the fuel.

Figs. 2 and 3 show there was only a small rise of fuel temperature from the tank through the pump and to the cooler inlet, a small change from the cooler to the carburetor, and that the fuel was cooled when it entered the carburetor bowl. Fig. 2 shows the effectiveness of the cooler.

The pressures measured were as follows: At the pump inlet, pressures from -1.25 to $+1$ in. of mercury referred to static pressure were read during all types of flying and power conditions for which this airplane would be used. The pressure at the pump outlet was 10 to 15 percent greater than the carburetor inlet pressure which in turn varied between 3 and 4 lbs. per sq.in. The pressure in the bowl fluctuated, but the average absolute pressure at sea level was a little more than an inch of mercury below static pressure and at 18,000 ft. it was a little less than an inch of mercury below static pressure. The fluctuations noted were very erratic and amounted to 50 percent of the average depression. Likewise, the variations of the bowl depression were followed by similar variations in the Cambridge exhaust-gas analyzer readings.

The curves of Fig. 4 show variation of vapor pressure of fuel with change of absolute pressure. (See reference 2.) This relation may be used for evaluating the conditions in the fuel system with regard to the tendency of the fuel to boil. Unfortunately, no thermocouple was installed in the fuel system for tests when the hottest fuel was used, but a representative case for which measurements were made was as follows: A climb test was made early in the morning, with ground air temperature 77°F. The fuel entered the carburetor at 77°F. at the start of the climb and at 74° at the end. The engines stopped at 15,000, 17,000, and 20,000 ft. Measurements described in the previous paragraph showed that the lowest absolute

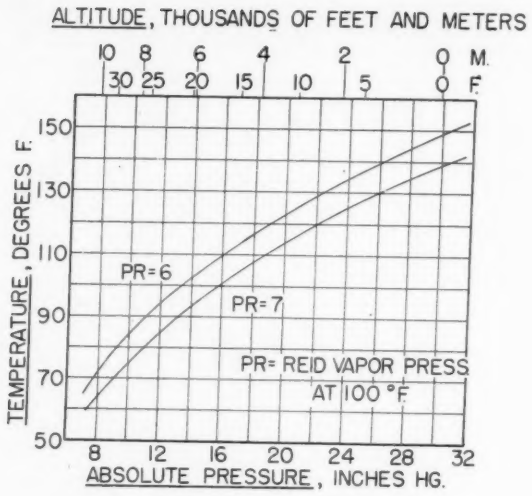

FIG. 4. Fuel ebullition temperatures.

pressure and highest temperature combination occurred at the pump inlet. With a depression of 1.25 inches of mercury referred to static pressure it may be seen by reference to Fig. 4 that the fuel was 32°F. cooler than its ebullition temperature when the engines stopped at 15,000 ft. altitude. Erratic variation of mixture strength occurred as well as the engine stoppage.

Notwithstanding this wide margin between the results of the survey and the theoretical conditions for vaporization of the fuel, seemingly important information had been obtained, namely, that cooled fuel had given improved results. A climb to 18,000 ft. had been made with fuel coolers and no engine stoppage, and a climb immediately afterward with the coolers blocked off had resulted in engine stoppage at 15,000 ft. Coolers were therefore permanently installed in an airplane and tested. By this time the weather had become colder but the engines still stopped, as before, although at slightly higher altitudes, namely, 16,000, 17,500, and 19,500 ft.

This last result made it necessary to discard the idea that fuel temperature was the important factor and to follow another line of attack, suggested by the observations of float bowl pressure fluctuations.

VAPOR SEPARATORS

A small very crude vapor separator was then installed for each engine in the fuel line near the carburetor inlet. This device was simply an enlargement in the feed line with a $^1/_4$-in. bleed line running back into the fuselage, through a valve and a sight glass. The bleed line did not carry away enough fuel to affect the fuel pressure.

Climbs were made with the valve in the bleed line open. At sea level, fuel with no bubbles flowed but when an altitude of 3000 ft. was reached an occasional bubble passed through the sight glass. Then at

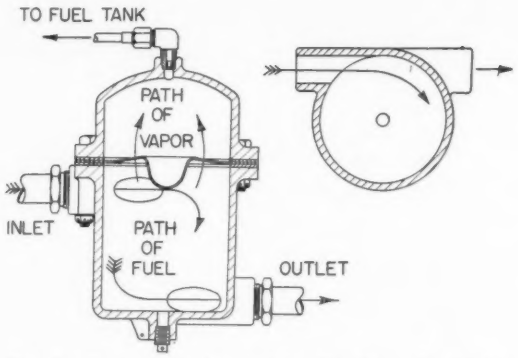

FIG. 5. Vapor separator used by The Glenn L. Martin Company.

11,000 to 15,000 ft. the mixture passing through the sight glass had become predominantly gas with some liquid. The engines did not stop while the separator bleed lines were open, but in flights made during cold weather the engines would stop immediately or within a few seconds whenever the bleed line valves were closed at an altitude of 19,000 to 21,000 ft.

The simple separators first tried were not very efficient because they did not provide adequate means of slowing down the flow and permitting segregation of the gas from the liquid phase. Some gas was still entering the carburetor bowl because the mixture strength still varied erratically, although it was steadier than it had been before.

This demonstration showed that a great deal of permanent gas was liberated from the fuel after the absolute atmospheric pressure had been diminished, and that the removal of this gas from the fuel would improve engine operation.

The next step was to prepare a more efficient separator. One form had a float and needle valve above the separating chamber designed to open only to gas and to prevent flow of fuel through the bleed line. In flight this device showed valve chatter caused by vibration. Another form was provided with a small metering orifice and bleed line emptying back into one tank in the airplane (Fig. 5).

A check of the fuel system for leaks permitting air to get into the fuel revealed one possible leak, that is, through the primer line and primer pump. The primer line leads fuel to the supercharger case and, therefore, during flight is subjected to a pressure above atmospheric. By reproducing flight conditions a leak was found, but it was quite small.

It was of interest to see whether the restrictions to flow, and turbulence produced by the fuel lines and fittings, caused any appreciable amount of gas formation. For this purpose one engine was temporarily supplied by a line running directly from the nearest tank without a valve or any fittings not absolutely necessary. The line was $^3/_4$ in. diameter throughout and the separators were not used. Thus equipped,

this engine performed slightly if any better than the other engine on the climb test, although laboratory tests have shown constrictions and bends to be undesirable.

Climb tests were made with an experimental separator of the design shown in Fig. 5 during the period of November, 1937 to January, 1938. Not only was there no trouble from engine stoppage but the fuel-air ratio as shown by the Cambridge indicator remained steady. Slight readjustments of the mixture lever were required as the climb progressed, and the responses of the Cambridge instrument were always consistent with the sense and magnitude of changes to the mixture control lever. These tests were carried to heights over 26,000 ft.

Final Test of Production Model Separator

During the first week of May, 1938, flight tests were made with an airplane equipped with vapor separators constructed by factory production methods. For the duration of the tests the bleeder line of one separator was run to a glass measuring apparatus for measurement of the quantities of liquid and of gas passing through the line. The air temperature was 80°F. at the ground, and remained at least 13°F. above standard altitude temperatures to an altitude of 23,000 ft., nearly comparable to the hot weather experiences mentioned above.

The rate of climb of this airplane was over 1800 ft. per min. at sea level and 1300 ft. per min. at 16,000 ft. altitude.

The gas was observed to pass through the line as an occasional bubble when the airplane was in level flight at cruising power at sea level, and during a full power climb the rate of gas flow increased to a maximum at 10,000 ft. altitude and then dropped off to almost no flow at 23,000 ft. The maximum flow was 660 cu.cm. per minute reduced to standard conditions, or 14.25 percent of the volume of the fuel used.

A sample of the gas was analyzed in an Orsat apparatus, giving the following result:

CO_2	1.3 percent by volume
O_2	18.1 percent
N_2, and inert	51.1 percent
Combustible	29.5 percent

This indicates that roughly 70 percent of the gas separated was made up of air and the remainder came from the fuel. The constituents of air therefore amount to 10 percent of the volume of the fuel, a reasonable check with published information on the solubility of air in fuel.[3]

Conclusions and Recommendations

From the results of this investigation it is apparent that the relatively large amount of gas contained in solution becomes separated when the absolute pressure on the fuel is diminished by climbing to a high altitude if agitation, such as that from a fuel pump and relief bypass, is present.

At moderate temperatures (15°F. above standard altitude temperatures) the dissolved gases are made up in large proportion of the constituents of air.

The elimination of most of the fittings and valves needed in a twin-engine airplane and the use of a large fuel line with "easy" bends did not noticeably improve the performance of the system. In the summer, fuel coolers gave some improvement but in the winter none whatever.

The operation of carburetors in which mixture strength is controlled by means of float bowl suction is violently upset by the quantity of gas liberated from aviation fuel during a fast climb.

If a conventional pump is used, a vapor separator is necessary for proper operation of the type carburetor used during these tests. For operation to 26,000 ft. the separator installed in the carburetor feed line gives perfect operation, and it is probably simpler, lighter, and more dependable than any system in which a pump without a relief valve is used because of the complexity and cost of the equipment necessary with such a system.

References

[1] Aspelin, L. L., *High Altitude Fuel System Investigation*, Air Corps Technical Report No. 4404, July 27, 1938.

[2] Bridgeman, O. C., and White, H. S., *The Effect of Airplane Fuel-Line Design on Vapor Lock*, S.A.E. Journal, October, 1930.

[3] Bridgeman, O. C., and Aldrich, E. W., *The Properties of Gasoline with Reference to Vapor Lock*, S.A.E. Journal, July, 1930.

Institute Notes

Simultaneous Lecture Series

The Institute will inaugurate, on December 17, a series of illustrated lectures to be given simultaneously at all of the Institute Branches at intervals of about one month. The lectures will be supplied by the Institute in printed or mimeographed form with 35 mm. positive projection strips of the illustrations. The lectures will be delivered by a member of each branch who is familiar with the field with which the lecture deals.

The series will receive an auspicious start with Dr. Hugh L. Dryden's Wright Brothers' Lecture on "Turbulence and the Boundary Layer," which will be delivered on December 17 at about 30 Branches, as well as in New York.

The subject matter of the lectures will be carefully chosen to be of general technical interest and will include the latest developments in aircraft, instruments, apparatus, etc. In addition to the lectures which specialists in the United States will be invited to prepare, the Institute will solicit lectures from foreign specialists and aeronautical societies.

The Institute plans to supply a one-hour program each month through June, 1939. The programs will usually consist of two half-hour lectures with illustrations. The Branches will in many cases expand the program to two hours or more with local papers.

Annual Meeting—1939
Honors Night Dinner

Tentative programs of the Annual Meeting of the Institute covering three days during the last week in January, 1939, will be in the hands of the Institute members by December 25.

One of the features of this meeting will be a daily weather map analysis and discussion lasting about fifteen minutes and taking place sometime between the regular morning and afternoon sessions. Prof. G. Emmons of New York University will prepare the 8 a.m. weather map and have lantern slides made to facilitate discussion of the interesting features of the current synoptic situation.

The Honors Night Dinner and Meeting, usually held on December 17, has been postponed until Friday, January 27, 1939, because of the fact that Mr. A. H. R. Fedden, President of the Royal Aeronautical Society, who was to be the guest of honor, found it impossible to leave England at this time.

At the Dinner in January the Sylvanus Albert Reed Award, and the Lawrence Sperry Award will be awarded. The newly elected Fellows of the Institute will be given their certificates and the next President of the Institute will be inaugurated.

Air Transport Meeting

The Air Transport Meeting of the Institute held at the Hotel Morrison in Chicago on Friday and Saturday, November 18 and 19, 1938, was an outstanding success both from the technical standpoint and from the standpoint of attendance. About 250 people from all parts of the country attended the sessions.

The first paper on the morning session, which was presided over by William Littlewood, was by W. B. Oswald of the Douglas Aircraft Company, on "Operating Safety and Requirements of the Modern Transport." It dealt with the factors particularly with regard to take-off and landing problems, which should be taken into account in the design of modern transport planes. The second paper by Wellwood E. Beall, of the Boeing Aircraft Company, was a description of the problems encountered in the design of the Boeing Trans-Atlantic Clipper and steps taken in their solution. A detailed description of the passenger and crew accommodations making for comfort and efficient operation of the aircraft were given. This was followed by a description of the Curtiss-Wright 20 air transport by George A. Page, Jr., of the Curtiss-Wright Corporation. Structural, aerodynamic, and power plant features were described.

The chairman of the afternoon session was J. A. Herlihy. Mr. George E. Woods Humphery, formerly of Imperial Airways, described features of the Mayo Composite Aircraft. Col. A. D. Tuttle, of United Air Lines Transport Corporation then presented a paper on aeronautical physiology in which the physiological problems connected with high altitude operation and landing and take-off of aircraft, along with current methods for their solution, were described.

There followed a Symposium on Air Transport Operating Problems. A paper by L. G. Fritz, of Transcontinental and Western Air, dealt with the economics and problems of high altitude operation. Meteorological and economic problems connected with supercharging cabins seem to indicate a "most efficient altitude" of about 20,000 feet for long distance transport operations. Charles Froesch of Eastern Air Lines followed with a paper on the economics of local schedule operation with particular reference to short haul operations. The advantages of operating at lower proportions of the available horsepower and the resultant small sacrifice in schedule time were stressed. The last paper of the afternoon session, by R. E. Johnson of Wright Aeronautical Corporation gave the possible advantages of constant Brake Mean Effective Pressure engine operation over the almost universal practice of operating at constant r.p.m.

At 7:00 p.m. on Friday evening, a unique buffet supper was served in the Casino room of the hotel. The various air lines participating brought delicacies from various cities on their routes. Eastern Air Lines brought oranges, Pan American Air Lines, coffee; Chicago and Southern, shrimp; T.W.A., celery; Northwest Airlines, apples; Mid-Continent, pink grapefruit; Pennsylvania Central, vegetables; United, New England crabs; American Airlines, turkey, etc.

Following the supper an interesting program of talks was provided. Mr. George E. Woods Humphery, formerly Managing Director of Imperial Airways, Ltd., spoke on "International Air Transport Cooperation." Mr. Woods Humphery gave a historical account of the gradual expansion of the Imperial Airways and told of the many specialized problems encountered in a service operating over so many different countries and under such varied climatic conditions. He described the Mayo Composite airplane development and predicted that it would prove to be a great step forward in the use of higher wing loadings. The plan for carrying all of the first class mail between England and the Dominions by air was explained and its importance to British trade emphasized. Commander D. W. Tomlinson spoke on "Notes on a Trip to Germany." He dwelt on the airport, airplane, engine, directional finding, and blind landing system developments in that country. He was particularly impressed by the extent of their military aviation development. Mr. Peter Riedel, Assistant to the German Military Attaché, then described his experiences in piloting gliders in this country, particularly those during his record breaking flight from Elmira to Washington. The program closed with a talk by Mr. Harold R. Harris, Vice-President and Operations Manager of Pan American Grace Airways, Peru, on aviation developments and opportunities in South America. The difficulties, largely due to the mountainous terrain and the altitude of airports, were recounted in an interesting and informative manner. Mr. Harris urged the further expansion of this country's aeronautical activities to the South American continent.

The Saturday morning session, presided over by Charles Froesch, opened with a paper by Lloyd Espenshied and R. C. Newhouse of Bell Telephone Laboratories on "The Terrain Clearance Indicator." The technical details, accuracy, and lines

for further improvement were described. Melvin N. Gough of the N.A.C.A. followed with a paper on stability from the pilot's standpoint. Desirable and undesirable stability features of present-day transports with special reference to landing and take-off were described. The next paper by H. F. Schippel of the B. F. Goodrich Company on "Rubber in Aviation" described the various uses of rubber in present-day airplanes. Technical features of the construction of tires and other equipment were given. Charles E. Colvin of the Kollsman Instrument Company gave the next paper on "Flight Altitude Control." The various precautions and corrections to be made in altimeter readings to get the true altitude were discussed. The effect of the free air temperature on the indicated altitude was stressed. J. Lyman and F. C. Mosely of Sperry Gyroscope Company followed with a paper describing the various instruments now available for instrument landings. It was concluded that the instruments now available are sufficient so that scheduled air transports will soon be making landings under conditions of zero visibility. The last paper of the meeting was by J. A. Herlihy, of United Air Lines Transport Corporation on "Economics and Engineering in Air Transport." It dealt with the various factors which must be taken into consideration in the design and development of air line equipment.

Indicative of the widespread interest in this meeting was the representation of foreign countries. Among those present were Mr. Peter Riedel, Assistant to the German Air Attaché; Mr. S. Shumovsky of the Armtorg Trading Corporation; Mr. G. C. Pirie, British Air Attaché; Mr. George E. Woods Humphery, England; Mr. Louis Giusta, France; and Lieut. Col. Andrzej Chramiec, Polish Air Attaché.

On behalf of the Air Transport Association of America, holding its Annual Meeting in Galveston, Texas, Col. Edgar S. Gorrell, President, sent the following telegram to Mr. Lester D. Gardner: "Best wishes from Annual Meeting Air Transport Association of America to Institute of Aeronautical Sciences in Session in Chicago. The sound and constructive work of yourself and associates along scientific lines is in large measure responsible for the continued improvement of air carrier service to the public."

The Institute wishes to express its appreciation to the various air lines for their cooperation in the arrangements and to the members of the Air Transport Committee, William Littlewood, Chairman, L. G. Fritz, Charles Froesch, Lester D. Gardner, Andre Priester, and R. W. Schroeder, who were directly responsible for the success of the meeting.

Rotating Wing Aircraft Meeting

The following brief account of the papers given at the Rotating Wing Aircraft Meeting held by the Philadelphia Chapter of the Institute on October 28 and 29, 1938, was not available for the November issue of the Journal.

On Thursday evening, October 27, Prof. Alexander Klemin of New York University gave an interesting review of the various types of rotating wing aircraft. The lecture, given at a regular meeting of the Franklin Institute, traced the historical development of these types and described their various features.

Ralph H. McClarren, Secretary of the Franklin Institute, gave a lecture on Friday morning, entitled "Review of Rotating Wing Aircraft." Interesting model demonstrations of the principles of rotating wing craft were given.

The first paper of the session on "Development and Improvement," presided over by Prof. Alexander Klemin, was by Richard H. Prewitt, of the Kellett Autogiro Corporation on "The Autogiro." He traced the development of the autogiro form from Juan De La Cierva's craft to the present time, describing such relatively modern features as the rotor starter, direct control, and the jump-off technique. Stability problems were described. Moving pictures of autogiros in flight, taking off, and landing were shown. The second paper of this session, by Gerard P. Herrick, was entitled "The Convertaplane." The features and problems were described and moving pictures of the convertaplane in flight were shown. H. H. Platt, of New York, followed with a paper on "The Helicopter" in which he developed the fundamental relations governing stability and controllability of the helicopter. The concluding paper in this session was by E. Burke Wilford of the Pennsylvania Aircraft Syndicate, on "The Gyroplane." He traced the development of the craft and recommended that tests be made of rotors with rigid blades.

The afternoon session on "Application and Uses" was presided over by W. Wallace Kellett. The first paper, by Hon. Frank J. G. Dorsey, a member of the U. S. House of Representatives, was entitled "Government Use and Development." He described legislation which has been enacted by Congress authorizing funds for the development of rotating wing aircraft and for the establishment of an experimental autogiro feeder mail line. There followed a paper by A. G. Galloway, of the U. S. Department of Agriculture on "Agricultural Uses." He dealt in particular with the adaptability of rotating wing aircraft for the dusting of crops. The next paper, by Lieut. H. F. Gregory of the Army Air Corps, on "Military Uses" took up in some detail the extent of the Army's interest in rotating wing aircraft. A school for pilots at Wright Field has been in operation for some time. The advantages of the aircraft for observation work were stressed. Moving pictures showed formation flying, landings, and jump take-offs. John M. Miller of Kellett Autogiro Corporation gave the next paper, on "Piloting Technique." The lecturer compared the piloting of airplanes with autogiros, describing differences and similarities. He experienced no difficulty in changing over from one to the other. He stressed the fact that the airplane pilot piloting an autogiro must accustom himself to flying speeds much lower than those considered safe in an airplane. The fact that the autogiro takes off with the tail down, and problems of stability, control, and vibrations at high speed are also important differences between the two. A paper by James G. Ray described "Unique Uses" of rotating wing aircraft. He described military, civil, and commercial uses, and his experiences piloting an autogiro while photographs of the Morro Castle fire were being taken, under conditions when all other aircraft were grounded due to low ceilings.

Dr. George W. Lewis was chairman of a Saturday morning session on "Research Programs." The first paper by Prof. Alexander Klemin and E. B. Schaefer dealt with the research program at New York University. A rig by means of which rotor tests can be carried out in the wind tunnel was described. Measurements by means of this suspension indicated a very marked scale effect on the autorotative characteristics of rotors. For this reason the rotors are power driven at the appropriate velocities during tests. Prof. Montgomery Knight then gave an account of the research program at the Georgia School of Technology. Past investigations on static thrust, ground effect, and level flight were described briefly and contemplated studies of the rotor stall, experimental investigation of the level flight and climb characteristics, and rotor drive were described briefly. The particular means of rotor drive being investigated involves driving the rotor by means of jets of air emerging from the tips. The preliminary work of developing an axial blower for furnishing air to the jet has been carried out and a blower rotor efficiency of 95 percent has been achieved. Preliminary tests of the thrust variations experienced by a single blade in forward motion were mentioned. A simple vibration absorber has been developed. The program also includes the design of a full-scale single-seater helicopter to determine the feasibility of the jet drive. Recent wind-tunnel tests on a one-quarter scale model gave encouraging results. R. A. Bailey followed with a description of the research program at the N.A.C.A. laboratories. He described several recent wind-tunnel investigations of rotors in the Committee's laboratories. Continuations of these tests are contemplated.

The second morning session, presided over by E. Burke Wilford was devoted to "Future Types and Developments." W. Laurence LePage read a paper by Louis Breguet on "The Helicopter in Europe." The Breguet helicopter, utilizing two rotors, one above the other, was described. The next paper, by Raoul Hafner, was entitled "The Hafner Gyroplane." He described technical features of blade articulation, stability, and maneuverability, and showed motion pictures of the gyroplane in flight. He also described his development of a single rotor helicopter and methods of counteracting the torque of the rotor. Paul E. Hovgaard of the Curtiss-Wright Corporation, gave a paper on "Future Types of Gyroplanes." After tracing the development of the autogiro and gyroplanes through to the convertaplane and the helicopter, he predicted that all of these types or combinations of them would be used in the future. He recommended particularly that work be done on types similar to the convertaplane in which a rotor is used for landing, and possibly for takeaff, and the desirable characteristics of the fixed wing airplane ore utilized for high speeds. W. Laurence LePage then read a paper by Prof. Henry Focke of Germany describing the successful Focke-Wulf helicopter. The meeting closed with a paper by Dr. Max M. Munk on "High Speed with Safety."

The banquet, held on Friday evening, was well attended. The program included a number of interesting talks by Edward G. Noble, Dr. George W. Lewis, Grover Loening, Raoul Hafner, R. H. Prewitt, and W. Wallace Kellett. Mr. Noble gave an interesting account of his experiences with rotating wing aircraft. He described the extent to which the Civil Aeronautics Authority, of which he is Chairman, will assist in the development of this type of aircraft. Dr. Lewis described some of the activities of the N.A.C.A. along this same line.

The representation at the meeting included over 200 people from all parts of this country as well as from foreign countries.

The success of the meeting is due largely to the committee in charge of the arrangements, composed of E. Burke Wilford, Chairman, Agnew E. Larsen, W. Laurence LePage, Richard H. Prewitt, James G. Ray, and Ralph H. McClarren, Secretary, and to the Philadelphia Branch of the Institute for their support.

Student Branches

Boeing School of Aeronautics. At a meeting on October 27, the films of European Aeronautical Laboratories were shown to ninety people, including thirty student members of the Branch. Mr. Walter McGinty led a discussion between reels.

Carnegie Institute of Technology. At a meeting on November 5, Professor Thorpe spoke on "Individual Research." A series of short talks were given by Senior Aeronautics Students who discussed inspection trips to various factories. The speakers and their topics were: George Fieldson—Piper Cub; Gene Whitacre —Lycoming; Olliver Rosstead—Jacobs engines; Charles Fegan —Sensenich propellers; Victor Saudek—Fairchild; Bruce Grimm—Martin.

University of Cincinnati. The first fall meeting, held on October 31, was broadcast over station WCKY. The subject of the Hughes and Corrigan flights was discussed. Frank Robinson explained the maps and navigation methods used by Hughes. Sidney Batterson talked about the instrumental equipment and Raymond Bisplinghoff described the engines and propellers.

University of Detroit. The first meeting of the school year was held on October 20. Captain George Haldeman, former trans-Atlantic flier and present Civil Air Authority inspector for Michigan was the principal speaker. The officers for the coming year are: Frank Wozniak, Chairman; Paul Bikle, Vice-Chairman; John J. Beckman, Secretary; Kenneth Smith, Treasurer. The membership of the Branch is 33.

At the second meeting, on November 17, the Continental Trophy was presented to Edward Clark. The trophy, sponsored by Continental Motors, is awarded annually to the student who, in the opinion of the judges, has produced the best design of an airplane as part of his Junior courses in airplane design. Frank Wozniak placed second. Speakers from the General Motors proving grounds, and movies of the Pan American Rio Cruise, completed the meeting, which was held in conjunction with the S.A.E. Student Branch at the University.

University of Michigan. At the second meeting of this Branch, held on November 10, various inspection trips were discussed. It was decided that the Branch as a group would attend the Air Transport Meeting at Chicago.

University of Minnesota. The second meeting of the year, held on November 2, was devoted to an illustrated lecture "A Year on White Face Mountain" by Mr. Serebreny. The lecture dealt with the experimental government station on White Face Mountain and showed many of the meteorological instruments in use there. Donald O. Q. Lampland, Vice-Chairman of this Branch, has been elected to the office of President of the Senior Class.

Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. Any member or organization may have requirements listed without charge.

Wanted

Production or Design Engineer with recent experience in constructing metal airplanes. Knowledge of comparative cost and time elements involved useful though not essential. Reply Box 76, Institute of the Aeronautical Sciences.

Available

Aeronautical Engineer, B.S.E., (Ae.E.) and Ae.E., author, inventor, Major, Air Corps Reserve, with 22 years' experience in the design of commercial and military airplanes, desires position as Project Engineer or Designing Engineer. Reply Box 77, Institute of the Aeronautical Sciences.

Necrology

Leslie MacDill

Colonel Leslie MacDill, a Fellow of the Institute, was killed when an Army combat plane he was piloting crashed in Washington, D. C., on November 10, 1938.

Colonel MacDill was at the time of his death a Staff Officer with the General Staff of the War Department. He was born in Monmouth, Illinois, on February 19, 1889. He received an A.B. degree from Hanover College in 1909, a M.A. degree from Indiana University in 1911, and a D.Sc. degree from the Massachusetts Institute of Technology in 1922. He entered the U. S. Army in 1912 as a Second Lieutenant. Since 1914, when he entered the Signal Corps Aviation School, he has been associated with the air arm of the service. During the war he attained the rank of Major and was a Staff Officer with the Air Service Headquarters of the A.E.F.

In 1922, he became Assistant to the Commanding Officer at McCook Field, Dayton. In the following year he was assigned as Chief Engineer Officer of the Engineering Division at the same field, and, with the exception of one year which was spent at the Command and General School at Fort Leavenworth, he occupied this post until 1929.

In 1930, Colonel MacDill was assigned as a Staff Officer in the Office of the Chief of the Air Corps. In 1934 and 1935, he spent one year each at the Army and Navy War Colleges. Since 1935, he had been Staff Officer with the General Staff of the War Department.

Book Reviews

Mechanics for Engineering Students, by JOHN E. YOUNGER; International Textbook Company, Scranton, Pennsylvania, 1938; 461 pages, $3.50.

This book is designed as an introduction to analytical mechanics and is eminently suited to use as a textbook in engineering courses. The material has been used by the author for a number of years in teaching sections of a class of 500 students at the University of California. The subject matter is treated from a wide viewpoint, making it suitable for engineering courses in all departments; such as mechanical, electrical, civil, mining, chemical, etc.

The book is divided into five parts: Statics, Kinematics, Dynamics of Rigid Bodies, Methods of Momentum and Energy, Method of Dimensions. The subject matter is arranged in logical order, leading from the fundamental to the more involved concepts. In addition, the 635 problems are arranged in each chapter in the order of increasing difficulty.

As is to be expected in the light of Prof. Younger's wide experience in aeronautics, the subject matter of the book includes particularly excellent treatments of those topics which are necessary to the well rounded aeronautical engineer. Two of these are, an introduction to the methods of vibration study, and the methods of dimensional analysis. The material on vibration will acquaint the student with the fundamental principles and serve as an introduction to this important and, in its practical applications, often very involved subject. The powerful methods of dimensional analysis are indispensible to the aeronautical engineer, regardless of whether his work is confined to aerodynamics or structures. This is probably one of the best features of the book; the analysis is applied to both aerodynamic and structural problems and the student is assured of an understanding of the fundamental principles early in his career. Another noteworthy feature is the inclusion of many aeronautical problems, especially in the part on dynamics of rigid bodies.

Each of the five parts begins with a brief historical treatment of the development of the methods employed from their conception to their present refinement.

As a prerequisite the student is assumed to have a fair knowledge of mathematics up to and including integral calculus.

This book should be widely used as a text and as an excellent and concise review of the principles of mechanics. Prof. Younger seems to have achieved the happy medium of presenting the material in concise form without sacrificing anything in the way of clarity.

Formulas for Stress and Strain, by RAYMOND J. ROARK; McGraw-Hill Book Company, New York; 326 pages; $3.00.

In the words of the author, "this book was written for the purpose of making available a compact, adequate summary of the formulas, facts, and principles pertaining to strength of materials." It is intended primarily as a reference book, and, since a degree of familiarity with the field is pre-supposed, explanatory text is held to a minimum, and derivations are omitted.

The first 66 pages are given over to a brief discussion of fundamentals. Here we find chapters on definitions, symbols and units, behavior of bodies under stress, principles and analytical methods, experimental methods, and properties of a plane area. There is little in these chapters that is controversial or outside the working knowledge of the average engineer. It is regretted, however, that the author helps to perpetuate the unfortunate terminology in which "stress" and "unit stress" have different meanings. Section 19, "Remarks on the Use of Formulas," contains in two pages much common sense on the use of unfamiliar or doubtful methods.

Part Three is entitled "Formulas and Examples," and constitutes the bulk of the book, in both space and content. Of the 260 pages devoted to this part, 104 are taken up by tabulated formulas, arranged by subject matter in 18 tables. These tables fit naturally with explanatory matter, into chapters devoted successively to simple stresses, flexure, torsion, flat plates, compression members, pressure vessels, direct bearing and shear, elastic stability, and dynamic and temperature stresses.

As might be expected, the well-established theory of flexure of bars is treated in great detail. We find shear, moment, and deflection tabulated for 38 cases of lateral loading of straight beams. Form factors are tabulated for four materials in seven section shapes. Other tables treat flexural centers of sections, curved beams, circular rings, and combined axial and transverse loads. In the latter case all the standard loadings for single spans are given. Throughout the chapter brief mention is made of many related special conditions, such as lateral buckling, shear lag in wide flanges, tension field webs, etc. A notable omission arises in connection with continuous beams; the three moment equation is given for one simple case of lateral loading. The "precise" three moment equation is not mentioned. Other subjects are awarded less space, about in proportion to the extent of the related field of established current knowledge. Under elastic stability, for example, we find two tables, one giving 24 formulas for elastic stability of bars and rings; the other treats 35 cases of stability of plates and shells.

The references, some 245 in number, are adequate and well keyed to the subject matter, being grouped at the ends of chapters. In most cases, the references are keyed directly to the tabulated formulas.

The utility of such a work must depend on individual preference; for that reason the reviewer has attempted to be more descriptive than critical. The book has not been written from the special viewpoint of any one field of engineering; the scope of the work should be entirely adequate for the aeronautical engineer in all his routine work except that of thin shell design.

ROBERT S. HATCHER
Bureau of Aeronautics
U. S. Navy Department

Luftfahrt-Fachheft 1938, Deutsche Motor-Zeitschrift, Dresden A. 19, 63 pages, R.M. 2.

This pamphlet presents a survey of the airplane and engine industries in Germany. Descriptions of plane and engine types are given. About 100 photographs illustrate the text. The pamphlet is designed as a handbook on the present status of the plane and engine building art in Germany.

A. M. Fuel Systems for Aircraft, by BASILE DEMTCHENKO; Gauthier-Villars, Paris, 1938; 234 pages.

This book with an introduction by Paul Dumanois, General Inspector of Aeronautical Research and Instruction at the French Air Ministry, is a very welcome addition to our technical library. It is virtually a handbook on fuel systems and can be used by the airplane designer for calculating fuel systems and should enable him to assure himself that the system will function when assembled.

The first part of the book covers in simple and understandable language a brief study of fuel systems, the location and functioning of the various apparatus comprising a fuel system, practical rules for installation, representative installation diagrams, auxiliary installations (for refueling), special devices, and examples of actual installations.

The second part of the book covers the factors influencing the flow of fuel, pressure and gravity feed systems, and calculations.

If the calculations are found to correlate with actual operation of fuel systems, then these data contained in this book will be of inestimable value to the designer.

Also, if vapor-lock studies in this country check the formulas developed by Dr. Demtchenko then the labor in reducing these formulas to practice by obtaining information in the laboratory on pipes and fittings as used in this country will be reduced greatly.

The author, his colleagues and the A. M. Establishment are to be congratulated on their effort.

ARTHUR NUTT
Wright Aeronautical Corporation

Leaves from an Old Log, by GILL ROBB WILSON; privately printed, 1938; for sale by American Aviation Associates, Washington, D. C., 99 pages, de luxe edition bound in leather, $5.00.

There have been many poems written on aeronautics, but none have the background of experience and the sincerity that is found in this volume by Captain Wilson. He has been a pilot since 1917. He flew with the French Escadrille 66 and later with the A.E.F. He was decorated for gallantry in combat and survived several major crackups. He has followed an aviation career continuously, and for the past seven years, has been State Director of Aviation for New Jersey.

In these thirty-six poems, he not only uses the language of the pilot, but embellishes it with the skill that comes from a life of introspection and devotion to his chosen speciality. He has captured the real meaning of aviation as few ever have.

In "The Man at His Back," a poem dealing with the fight he and his younger brother engaged in over Champagne, and in which his brother was shot down, he pays a moving tribute to combat aviation. As typical of the spirit of the work, the last verse is quoted:

> And that's why I'm rich in the ways of the sky,
> But so poor in the wealth of the world;
> For all I have done with the dreams of our youth
> Is to keep the sky banner unfurled,
> And flight must repay me by girdling the earth
> With the gift of its blessing for men
> Before I lie down in the yard by the manse
> With the man at my back once again.

Instrument Radio Flying, by KENNETH S. DAY; Air Associates, Inc. 1938; 284 pages; $3.50.

This book is intended solely for the use of pilots—scheduled, military, or sportsmen. It is designed to serve either as a "self-instructor" or as a supplementary guide to those under instruction in blind flying. As "blind flying" instructor and check pilot for American Airlines, Mr. Day has, for the past six years, made notes and prepared booklets on instrument flying. These have been expanded into the present book.

Chapters on instruments and their use, characteristics of radio ranges, radio range flying, instrument approach procedure, instrument flight test, radio and written tests, radio compasses, instrument landings, and procedures on the airways and two appendices on the two station interphone system, and examination for radio telephone third class license, comprise the text.

The style of presentation is personal and in the vernacular of the pilot. The use of formulas and intricate diagrams is avoided; the result is a simple and direct presentation of the information required for the most effective use of airplane instruments.

A chapter on "Procedure on the Airways" which covers all of the new requirements for pilots, should be particularly useful to the pilot.

It is seldom that a book is received which gives such evidence of its preparation through actual experience in the field. For any pilot the book will serve as an indispensible handbook on subjects which have as their object greater safety in flying.

Air Attack on Cities, by J. THORBURN MUIRHEAD; George Allen and Unwin, Ltd., London, 1938; 128 pages, 4s. 6d.

While this book will be of greater interest to architects and local government officials than to aeronautical engineers, it nevertheless is an excellent argument for a strong air defense. To the best of our knowledge it is the first book which studies the vast architectural and structural problems to be met in the event of air warfare. It gives only a sketchy outline of remedial measures, but it does indicate the changed conditions which will have to be met.

The book opens with a chapter contrasting the damage possible by air bombardment at the present time with that possible during the last war. The great increase in numbers, range, and bomb carrying capacity of planes makes hitherto isolated countries vulnerable to attack.

The author then describes the effects of aerial bombs and chemical warfare and the requirements for protection against them. Underground railways, which, during the last war, could be used for refuge, will be places of danger, since they will act as reservoirs for poison gas. Further, since the protective effects of gas masks and gas proof clothing are of short duration, the author contends that the solution lies in making new and existing buildings as gas- and bomb-proof as possible. Measures to be taken in the case of existing buildings are given and the requirements for new buildings that will withstand destruction are given in detailed drawings. It is of interest to note that the American type of steel construction with shells of stone and concrete floors ranks high in safety.

Specifications for concrete gas- and bomb-proof shelters are stressed and types of construction are given in detail.

At a time when the European countries are taking strenuous measures for defense against air raids it is evident how timely this book is.

My Life, by JEAN BATTEN; George R. Harrap & Company, Ltd., London, 1938; 304 pages; 8s. 6d.

Before the turn of the century, so-called "success stories" were confined almost entirely to the achievements of men—inventors, explorers, industrialists, etc. During the opening third of this century, women have gradually entered this field. Possibly in no specialized field have they acquired such a definite place as in aviation. A young woman can rapidly acquire the necessary skill and ability to pilot an airplane and, through determination and daring, gain world-wide fame. This has proved a lodestone to attract many ambitious girls.

A perfect example of such recognition is the life of Miss Jean Batten, one of the world's greatest women pilots, who today holds first place in the excellence of her achievements. At the age of twenty-eight, she holds many world records, those from England to Australia and New Zealand, and from England to South America being especially noteworthy.

In this book, she tells a straightforward story of how she began her career, the sacrifices she made to learn to fly, and of the almost instant fame she achieved by making solo, long-distance flights. The young woman from New Zealand makes no attempt to adorn her account with literary embellishments. She writes as from a well-kept diary or from an excellent memory.

This book will rank with Amelia Earhart's "Last Flight" and Elly Beinhorn's "Flying Girl" as an epic of women's progress in aviation.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aerodynamics

The First Chinese Wind-Tunnel. F. L. Wattendorf. Five-foot wind tunnel of the National Tsing Hua University in Peiping is of the return-flow type and circular in section throughout. Diameter varies from 5 ft. at the test section to 10 ft. at the large end of the nozzle and test section may be open or closed. Tunnel, balance system, uniformity of velocity, turbulence and airfoil calibration tests are described in detail. Use of the 5-ft. tunnel in the design of a 15-ft. tunnel (interchangeable 18-ft. section for full-scale propeller tests) also discussed. *Aircraft Engg.*, October, 1938, pages 317–318, 6 illus.

Large Steel Wind Tunnel Completed at M.I.T. Structure of the Wright Brothers tunnel is described. *Iron Age*, October 20, 1938, pages 28, 84, 2 illus.

Wright Brothers High Pressure Wind Tunnel. Massachusetts Institute of Technology's new high-pressure wind tunnel will allow investigation of substratosphere flight conditions and of the effects of high speeds on skin friction, turbulence and flow separations. Tunnel is capable of producing 400-m.p.h. wind velocities, and pressures ranging from $^1/_5$ to 4 atmospheres absolute, so that at the higher pressure figure, nearly full-scale Reynolds Number of 6,500,000 can be realized. Models having wing spans up to 8 ft. can be accommodated and the tunnel will reproduce in proper ratio, variations in barometric pressure up to theoretical altitudes of 35,000 ft. Description. *Aero Digest*, October, 1938, page 63, 3 illus.

Few details of tunnel. *Aviation*, October, 1938, page 60, 1 illus.

The Value of the Wind Tunnel in Aeronautical Research and Design. G. W. Lewis. Important part played by the wind tunnel in aeronautical progress, and a review of the development of wind-tunnel design. *U.S. Air Services*, October, 1938, pages 25, 27.

The National Physical Laboratory. One of the two new tunnels designed (14 ft. wide, 7 ft. high, two four-bladed fans) is for tests on complete aircraft. Circulation will take place within a continuous duct having transverse dimensions everywhere about the same as those of the working section. For the second wind tunnel the achievement of initial freedom from turbulence proved most difficult in design but various degrees of turbulence can be introduced and controlled at will. Another high-speed tunnel (working section 2 × 1 ft., 3 ft. long) will be fitted with parallel glass observation windows for photography of high-speed flow. These wind tunnels are described and the checking of results obtained by employing the pitot-traverse method in the compressed-air tunnel is discussed. Research in the Aerodynamics Department. To be continued. *Engineering*, October 14, 1938, pages 440–442, 3 illus.

Aircraft Design

Two Years' Technical Progress and Its Implications. Lt. General N. N. Golovine (author of "Air Strategy") and a Technical Expert present designs of strategic military aircraft and improvements urgently required in designs of the immediate future. Aerodynamically, twin-engined strategic aircraft capable of maximum speeds of 370 to 410 m.p.h. are considered possible at present. Developments necessary in aircraft, propellers, armament, armoring of aircraft, fuels and aircraft engines, especially the last, are discussed in great detail.

Boundary-layer control is considered the next step toward attainment of higher flying speeds. Characteristics and performance of a number of transports, bombers and fighters are presented in one table and those for proposed types of strategic aircraft (bomber, destroyer, scout and interceptor) in another. Military drawbacks of stressed-skin construction, vulnerability of retractable undercarriages as shown in the Spanish War, tricycle landing gear advantages, disadvantages of large wing area of four- or six-engined aircraft, and possibilities of an efficient bomber-fighter with variable wing area are taken up.

Armor-steel spinner for the propeller hub and armored cowling are considered essential but fighting value of an engine cannon is thought negligible. A destroyer aircraft with quadruple mounting of 25-mm. shell guns in the fuselage nose is preferred. Armor of the Soviet I.15 single-seater used in Spain is mentioned.

Data on various types of engines and for the proposed types are given and cooling discussed. More definite specialization in engines is considered necessary, and proposed types are classified according to their use for bombers, long-range fighters, and short-range fighters. Elaboration of a number of points raised in Chapter III of the author's "Air Strategy." *R.A.F. Quarterly*, October, 1938, pages 416–433, 6 tables.

Calculation of Critical Speed for the Two-Dimensional Case of a Wing with Aileron. G. Ellenberger. Critical speed of a two-dimensional wing with aileron without damping is calculated and the simplest form of computation is presented for use in practical calculations. In the appendix the modification of the mathematical scheme for the case of aileron damping is demonstrated. Report of Flight Technique Institute, Berlin Technical College. *Luftfahrtforschung*, August 20, 1938, pages 395–404, 3 illus., 2 tables, 24 equations.

Calculation of Downwash behind Wings. H. Multhopp. Convenient method for calculation of the downwash behind wings is presented which connects with the calculation of lift distribution. Factors which may have an effect on downwash conditions on the tail surfaces are considered. Physical fundamentals of the downwash problem, fundamental purpose of the calculation, and the effect of airplane form on the downwash ratio are also discussed. Report of the Goettingen Aerodynamic Institute. *Luftfahrtforschung*, September 10, 1938, pages 463–467, 3 illus., 1 table, 21 equations.

Changing over to "Boots." H. Parkinson. Conversion of landplane to seaplane is taken up with the formulas for calculating the following: float shape; position of water line and center of buoyancy; setting of floats relative to the aircraft; propeller-water clearance; metacentric heights; track of floats; float weights and c.g. position; c.g. of the complete airplane; aerodynamic resistance of floats; hydrodynamic data; and design of rudder. Data is applied to an analysis of a 4000-lb. seaplane. *Flight, Aircraft Engr. Sup.*, October 20, 1938, pages 67–68, 11 illus., 2 tables.

Comparative Cleanliness. R. M. Clarkson. Historical comparisons indicating the progressive improvement in streamlining. Streamline figures of merit are given for DeHavilland monoplanes from the early models up to the Albatross which can achieve an extraordinarily high combination of economy (ton-mileage of payload per gallon of fuel) with high cruising speed. Fine lines were inspired by original requirements of transatlantic mail carrying in which a range of 2500 miles against a continuous 40-m.p.h. head wind had to be achieved with a 1000-lb. payload. *Aeroplane*, October 19, 1938, page 475, 1 illus., 1 table.

Deviation of Airflow Boundary in the Presence of Wings with High Lift. C. Schmieden. Reference is made to an article in the February issue in which Reigels presented an approximate calculation for the deviation of the slipstream boundary in the two-dimensional case. The exact solution for this problem, given in the present article, has the advantage that only elementary functions occur and no series are added. *Luftfahrtforschung*, August 20, 1938, pages 392–394, 4 illus., 18 equations.

Minimum Drag of High Speed Airplanes. H. Eick. Influence of the thickness of the various structural parts of the airplane and cooling drag on the minimum drag. For present high-speed airplanes it is essential to estimate from the relation of their actual drag to their minimum drag the performance increase which may be expected due to aerodynamic improvement of the outer structure. Minimum drag is understood as the drag of the airplane, principal dimensions of which have been retained, at elliptical lift distribution and aerodynamically good design with highly smooth surface and no breaking away of the flow.

By evaluation of available results of measurements on airplane parts, a method is given for rapid determination of minimum drag, and the minimum drag of an airplane is computed as an example. Limits of the relation "minimum drag to actual drag" are presented for several high-speed airplanes of 1935 to 1937 design, and the possibilities of approaching the minimum drag are discussed. Data on airship hulls and fuselages are given in tables and test results shown in graphs. D.V.L. report. *Luftfahrtforschung*, September 10, 1938, pages 445–462, 24 illus., 4 tables.

Progress in Aircraft Design and Efficiency. N. A. V. Piercy. Airplanes and flying boats are considered more suitable for making long journeys with speed and economy as airships have failed to fulfill their early promise of exceptionally low tare weight in large sizes. Estimated range of airships can be reached by airplanes, although not by seaplanes, provided take-off is assisted. Progress made in aircraft and aircraft engines (as shown in the Bristol Perseus and Hercules, and the Rolls Royce Merlin engines) is pointed out.

Aerodynamic design problems which should be solved include: wing shape; true picture of the three-dimensional vortex system trailing behind wings and a precise knowledge of how this varies; exact effect of ground during take-off and landing; reduction of aspect ratio; and wing loading and provision of a large surge of power for take-off. *Inst. Mech. Engrs. Proc.*, 1938, pages 319–346.

The Slope of the Lift Curve. W. R. Andrews. Slope of the lift curve of a rectangular wing is shown to be practically a constant fraction of that of the elliptical wing of the same aspect ratio. From this it is concluded that for any given plan form of wing the slope is readily obtained from that of the elliptical wing by use of a suitable reduction factor. *Flight, Aircraft Engr. Sup.*, October 20, 1938, pages 68–70, 7 illus., 3 tables, 14 eq.

Wing Profiles at Imperfect Lift. F. Weinig. Position of the confluence point, or point where the two airstreams meet, is decisive for the magnitude of lift and moments of a wing profile. Position is affected by Reynolds Number, degree of turbulence of surrounding air (which varies greatly for free atmosphere, propeller slipstream and wind tunnels), surface roughness and influence of the boundary layer, such as suction, or blowing, and separation. When the point of confluence coincides with the trailing edge lift may be regarded as perfect.

Moment of the air force based on a point known as the center of the profile, is shown to be independent of the position of the point of confluence induced by flow conditions. From the resulting lift the moment can be computed, and vice versa. From the lift the position of the confluence point can be determined, and, exclusive of the immediate vicinity of the trailing edge, the pressure distribution along the profile surface can be found. D.V.L. report. *Luftfahrtforschung*, August 20, 1938, pages 383–391, 21 illus., many equations.

Investigation of Stability. S. Schneider. Explanation for deflection of the airflow in the region of the tail surfaces due to the passage of the flow over the wing, and calculation of the deflection. *Les Ailes*, September 29, 1938, page 7, 3 illus., 1 table, 4 equations.

Simplify Maintenance through Design. F. E. Nagel. Design features which, from the maintenance standpoint, should be incorporated in the ideal light transport. Recommendations cover: proper windshield installation; mounting of accessories in the cockpit for easy access for repairs, removal or servicing; successive installation of parts; fastening designs; making accessible the lines and fittings from instrument installations and the engine and control cables; making seat and back upholstery, cabin wall and head coverings easily removable; waterproof soundproofing; safety belt not requiring an engineer to apply; ventilation and heating systems; cowl and duct design points; retracting mechanism and other parts for landing gears; and radio installation. *Aviation*, October, 1938, pages 24–25, 72, 74, 2 illus.

Speed Efficiency. R. M. Clarkson. Simple method of calculating the Streamline figure-of-merit of an aircraft = $\frac{\text{Total Drag–Induc d Drag}}{\text{Skin Friction Drag}}$.

From the known altitude, speed, b.hp., propeller efficiency, total weight and equivalent monoplane span, the horsepower available and horsepower used in overcoming induced drag are evaluated. Horsepower used in overcoming total friction drag follows as the difference between these, and from it equivalent drag area of the aircraft is obtained. Calculation of skin friction drag is also explained. High figure of merit of 1.85 is calculated for the D.H. Albatross and compared with the figure-of-merit of several other aircraft showings it is considerably better than average modern radial-engined airliners. *Flight, Aircraft Engr. Sup.*, September 29, 1938, pages 59–61, 3 illus., 2 tables.

Twin Tails Revived? Design of a twin-engined twin-fuselage fighter airplane submitted by E. Albert to the French Air Ministry several years ago. Two engines of 500 to 550 hp. were to be placed in tandem with the crew between them in the central portion. Twin fuselages on each side would each carry a complete tail. Design was suggested as a dive bomber as the tandem arrangement would mean that with a fully feathering propeller one engine could be used to give an air drag effect during the dive. Few details only, and drawing. *Flight*, August 18, 1938, page 156, 1 illus.

Ultimate Speed. A. E. Parker. Possibilities of high-speed flight. Calculations given show that the maximum speed that a change in pressure can travel through a gas is the speed of sound in the gas. Speed of sound appears to be the upper limit for an airplane having no drag, and the upper limit for a practical airplane appears about 650 m.p.h. Best form for a high-speed airplane would be a flying wing with engines buried in the wing. Wing loading would be the optimum, 60 lb./sq. ft., for modern present-time aircraft and decreasing wing area would not produce an increase in speed. Calculations cover inflow velocity and tubes of flow and indicate that mass is independent of pressure. Speed of sound at various temperatures is shown in a graph and formula is given. *Flight, Aircraft Engr. Sup.*, August 25, 1938, pages 53–54, 1 illus., many equations.

Stress Analysis and Structures

Landing Stresses. D. Fraser. Qualitative estimation of the forces acting on a flying boat hull. Problem of the maximum force acting on a hull in landing is solved along the lines suggested by von Kármán. Simplified case of a wedge-shaped body dropping into a wedge-shaped wave and still water, respectively, is considered. Method used is to equate initial momentum of the wedge-shaped body to its later momentum plus the momentum of an "equivalent mass" of water. *Flight, Aircraft Engr. Sup.*, September 29, 1938, pages 62–64, 3 illus., many eqs.

Reinforced Skin. R. Rodger. Method of designing reinforced duralumin skin structures to withstand compressive loads is credited to the Curtiss corporation. Basic Curtiss data are elaborated and adapted to suit British standards. Data so obtained are applied and the theoretical allowable unit stress indicated is compared with that actually realized in a series of tests on an elliptical-section duralumin monocoque fuselage. Curtiss method appears to furnish quite a fair indication of the probable developed stress. *Flight, Aircraft Engr. Sup.*, August 25, 1938, pages 55–56, 2 illus., 4 tables.

Torsion of Built-Up and Reinforced Tubes. W. J. Duncan. Physical principles underlying the theory of torsion of compound tubes when the stresses are less than those causing buckling of any of the tube walls. St. Venant theory of the torsion of cylindrical bodies is considered, its mathematical consequences outlined, and certain conclusions are quoted concerning the torsion of solid cylinders the sections of which are very narrow. Torsion of simple thin-walled tubes is discussed and formulas developed leading to the familiar Bredt or Batho formula. To be continued. *Engineering*, October 7, 1938, pages 412–414, 1 illus., 12 equations.

Plastic Construction in Germany. von K. Riechers (Summary by M. Langley). Plastics position in the German aircraft industry. "Unfortunately the author does not have much to say about the German felt-like plastic for which a license was acquired by a small British aircraft constructing company some time ago. This material has been approved by Farnborough and complete aircraft units have been ordered for test. Results are promising enough for a well-known member of the British Aircraft Industry to interest himself. Meantime an even better British product, so we are told, is coming through its tests most successfully."

German article covers: Elements and basic materials of hardenable synthetic resins; fillers; subdivision of molding powders; outlook on future construction; position of research work at home and abroad; shear strength tests for permanent loads; synthetic fillers; earlier tests made by the D.V.L. on structural parts; and present applications to airplane construction. Strength figures for a laminated paper synthetic material and strength of glued joints in laminated materials, strength of synthetic materials for varying amounts of synthetic wool filler are shown. Glossary of German words and their English meaning included. Translation from *Luftwissen*, August, 1937. *Aeroplane*, October 12, 1938, pages 443–445, 6 illus.

Stresses in a Heavy Disk Suspended from an Eccentric Peg. R. D. Mindlin. Exact solution of the two-dimensional elasticity equations for small strain is obtained which satisfies the boundary conditions for a heavy disk suspended in a vertical plane from an eccentric peg of small diameter. *Jour. Applied Physics*, November, 1938, pages 714–717, 2 illus., 27 equations.

The Stressing of a Tail Boom System for Fin and Rudder Side Loads. J. Morris. In certain types of airplane the empennage is carried on two tail booms emanating from the main body. In some cases the booms and tailplane form what is virtually a portal and in these circumstances a fairly simple approximation may be found for the stresses resulting from fin and rudder side loads. Method described follows the treatment given in the author's paper "The Stressing of Rigid Jointed Frames." *Jour. Royal Aeronautical Soc.*, October, 1938, pages 872–875, 3 illus., 5 equations.

The Theory of Torsion-Bending. J. Lockwood-Taylor. Calculation of differential bending stresses in a two-spar wing under torsion is a simple procedure, but when the two members in differential bend form part of a continuous section conditions are somewhat altered. General theory applicable to such cases may be called the theory of torsion-bending. Results of this theory are summarized and proofs given in the appendix. *Aircraft Engg.*, October, 1938, pages 313–314, 1 illus., many equations.

Torsion of Built-Up and Reinforced Tubes. W. J. Duncan. Introduction to the theory of the torsion of compound thin-walled tubes; torsional stiffness in compound tubes; analysis of the stresses in a compound tube; cases of the double and triple tubes; pair of interpenetrating tubes; simple tube with corrugated reinforcement; torsionally ineffective walls; and mechanical analogues of the torsion of compound tubes. Concluded. *Engineering*, October 21, 1938, pages 467–469, 5 illus., 13 equations.

Aircraft Accessories

A "Dry" Undercarriage Leg. German Kronprinz undercarriage leg uses neither air nor oil. Springing and damping are both effected by two stacks of concentric rubber rings of which the outer have their inner faces bevelled while inner rings have their outer faces bevelled. When the load comes on the leg these inclined planes slide into one another, and inner rings are compressed while the outer are expanded. Short description. *Flight*, October 20, 1938, page 346, 3 illus.

Hydraulics in Production. New plant and methods of production of the Aircraft Division of Automotive Products, Ltd. The (British) Lockheed hydraulic components produced include controlling selector valves, a variety of jacks and rams for operating retractable bomb racks, trailing-edge flaps, undercarriages, and wheels. *Aircraft Engg.*, October, 1938, page 333, 4 illus.

Pre-Selected Flap Positions. New Dowty hydraulic preselector control enables the pilot to set flaps, radiator shutters, or landing lights in any predetermined position over their range of travel. Control also carries a position indicator. Two or three flaps can be operated by one control and are automatically synchronized. Drawings only. *Flight*, July 7, 1938, page 29, 2 illus.

Testing Brakes. Mintex-Halo instruments for investigating performance and temperatures of automotive brakes including the U-tube decelerometer, device for measuring foot pressure on the brake pedal, and a pyrometer capable of recording actual brake friction surface temperatures while brakes are in use. Description of equipment, test procedure and results. *Automobile Engr.*, July, 1938, pages 250–252, 10 illus.

Nose Wheel Design Loads. Bruce Smith. High taxiing loads with tricycle landing gear. Adequate strength in side load should be provided, based on some maximum acceleration applied to the pilot, the theory being that, in an unbanked turn on the ground there is some factor above which the pilot would experience difficulty in keeping his seat because of centrifugal force. This factor would be modified by the characteristic of the stable nose wheel to stiffen at high speed, so that a high-speed turn would be impossible in many cases even with unsymmetrical engine thrust and by use of brakes. Ground reactions are discussed and a principal design nose-wheel load is specified in terms of the gross weight of the airplane, dimensions of the landing gear, and a factor to cover deceleration. *Aero Digest*, October, 1938, pages 68, 79, 2 illus.

Running the Lee-Way Down. Experiences in taking off and landing in a 25-m.p.h. cross wind in the Arpin monoplane fitted with Dowty tricycle landing gear which has been given certain properties patented by O. F. MacLaren. Wheels are set to an angle of 14° from axis of the airplane. *Aeroplane*, October 5, 1938, page 422, 1 illus.

Aircraft Flight Testing Equipment

Measurements of Control-Surface and Flap Moments in Flight Tests. R. Schmidt. Special measuring device for recording force in the control lever consists of two tubes sliding one inside the other, relative displacement being controlled by a number of leaf springs arranged on a crosshead. Deflection is recorded by the D.V.L. scratch method. From the force in the control rod the moment can be computed from dimensions of the lever system. Measuring device and measuring procedure are described and measurements performed with this apparatus on the landing flap of an airplane are given.

Comparison with results of corresponding wind-tunnel tests showed considerable differences. Air flow around the flap or aileron is not affected to a very marked extent if the width of the slot is appreciable. Flow is thus determined by the Reynolds Number of the fitting rather than of the complete wing. Relatively large models may be required for reliable data. Report by Dornier Company. *Luftfahrtforschung*, August 20, 1938, pages 405–408, 12 illus.

The Vibration of Aircraft. F. G. Barlow. Vibrograph described was designed and developed at the Royal Aircraft Establishment for obtaining a quantitative analysis of aircraft vibration. Its calibration, method of mounting and exact location in the aircraft are discussed. A satisfactory method of analyzing the records obtained is outlined with a criterion for unpleasant vibration. Sources of vibration encountered during investigations are taken up and it is shown that the source of a particular vibration can be inferred after analysis of the records. Instrument operates on the seismographic principle, the case being rigidly attached to the vibrating member and spring-controlled and a suitably damped mass remaining stationary in space when subjected to high-frequency vibrations. Relative movement between case and mass is magnified and recorded. *Aircraft Engg.*, October, 1938, pages 301–305, 11 illus.

Aircraft

Arriba Espãna. C. G. Grey. Russian-built version of the Martin bomber used in the Spanish War (Russian-built Hispano-Suiza engines) is a clumsy brute but fast. Russian-built Boeing monoplane fighter seems the best of the Red fighters, but it is so fast and its wings are so small that it cannot turn quickly in a dog fight and workmanship is rough. Wings of the Curtiss biplane (gull-winged type) fall off if the airplane is suddenly pulled out of a dive. A crashed Grumman biplane is full of Pioneer instruments and workmanship is distinctly American. Table gives the number of Red airplanes of each design shot down during 1937 and 1938, of these 349 being of Curtiss design, 118 Boeing, and 92 Martin bombers. Airplane machine guns run from old type Lewis and Vickers .303 up to the latest 20-mm. shell-firing machine guns. These details are presented in a general account of Mr. Grey's recent visit to Spain. *Aeroplane*, October 5, 1938, pages 406–409, 5 illus., 1 table.

BELGIUM

The Renard Fighter. Trials with the new Belgian Renard R.36 single-seater fighter monoplane (Hispano-Suiza Series Y engine) have shown a top speed of more than 310 m.p.h. Trouble was experienced with the retractable radiator which is now replaced by one of more normal design under the fuselage. Of the six machines nearly finished one will have clipped wings, another an extra seat and dual controls, and a third a two-row radial engine. Brief reference. *Flight*, July 14, 1938, page 38.

CZECHOSLOVAKIA

Tatra T-201. Two-seater training and touring airplane. Hirth-Lizenz HM504 inverted inline 100-hp engine. Top speed 225 km./hr., cruising 195 km./hr., range 800 km. Short description, characteristics, and performance. *Luftwissen*, August, 1938, page 301, 1 illus., 1 table.

FRANCE

French Military Aircraft. Bréguet 690 may be adapted as follows: C3 three-seater fighter, A3 long-range reconnaissance, B2 light bomber, and AB2 light bomber and ground attack airplane. Armament, weight, and performance are given for the three models each with two types of engines (two Hispano-Suiza 14AB engines each developing 680 hp. at 3500 meters, or two Gnôme Rhône 14 Mars engines each developing 680 hp. at 4000 meters). The fighter has the highest top speed, that of 490 km./hr. at 5000 meters when powered by two Gnôme Rhône 14 Mars engines.

Hanriot 510 three-seater scout or reconnaissance airplane. Two Gnôme Rhône 9-Kfr 770-hp. aircooled engines. Top speed 350 km./hr. at 3000 meters, range 1350 km. Description, armament, performance. *Luftwehr*, August, 1938, pages 338–339, 2 illus., 1 table.

Latécoère Model 521 Trans-Atlantic Flying Boat. Model 521 is a six-engined twin-deck sesquiplane flying boat accommodating 70 passengers on limited runs, or 30 persons on a transatlantic service. Six Hispano Suiza 12 Ybrs 12-cylinder V-type watercooled engines, four driving tractor pro-

pellers, and two pusher propellers, inner pairs being arranged in tandem. Maximum speed 162 m.p.h. at 6560 ft. Cruising speed 142 m.p.h. Normal range 930 miles. Short description. *Aero Digest*, October, 1938, page 103, 1 illus.

Developing the S.E.200. First series of wind-tunnel tests has just been completed at Chalais-Meudon on the model of the 66-ton transatlantic S.E.-200 flying boat. Tests were for aerodynamic qualities and stability and were successful beyond expectations, but certain minor modifications are to be carried out before the second series of tests. Six 32-hp. electric motors on the model simulate the six engines totaling 9000 hp. The S.E.200, formerly the Lioré et Olivier 49, is the flying boat derived from the LeO 47 17-ton boat equipped to carry 20 passengers and crew of 8 as well as freight across the North Atlantic. Estimated top speed of 245 m.p.h. Cruising speed 200 m.p.h. Range 3750 miles. Brief note. *Flight*, October 20, 1938, page 337.

Guy de Chateaubrun. In an early experimental flight of the Delanne 20 (185-hp. Regnier engine) one of the best-known owner-pilots of France was killed. The Delanne was the flying model of a new two-seater fighter built for the Armée de l'Air and had several unorthodox features, among which was the position of the pilot almost in the tail of the airplane. As the pilot complained of gasoline fumes in the cockpit, it is thought probable that he was gassed for he made no effort to get the machine out of a spin starting at considerable height. Brief note. *Aeroplane*, August 17, 1938, page 213.

Potez 141 Military Cruiser Flying Boat. Potez 141 high-wing all-metal military cruiser flying boat is powered by four Hispano-Suiza 12-Y 930-hp. engines which should give it a maximum speed of 310 km./hr. and a range of 25 to 30 hours of flight. A 25-mm. cannon is provided in the central plane and bombs are disposed in the mountings of the end engines. Weight empty 12,000 kg. Total weight with overload 24,000 kg. Ceiling 5650 meters. Description, characteristics and performance with normal and overload. *Rev. de l'Armée de l'Air*, August, 1938, pages 935–938, 2 illus., 1 table.

The Tests of the "Ailette" Monoplane. "Ailette" experimental two-seater (Salmson 60-hp. engine), developed by C. Lauret, has Handley-Page slots and auxiliary flaps which should permit it to fly and land at speeds below 50 km./hr. Short description of design and performance tests. *Les Ailes*, Sept. 22, 1938, page 12, 5 illus.

GERMANY

Blohm and Voss Ha 139B. Improvements incorporated in the design of the Ha139B have increased its performance over that of the Ha139 used by Deutsche Luft Hansa in transatlantic test flights. Engines have been placed lower than those of the Ha139 so that upper sides of the engine cowlings conform better to the flow-sensitive upper surface of the wing, and give a better undisturbed flow distribution over the wing. Nozzle radiators are located in the lower side of the wing, and the fuselage is 20 cm. higher giving much more room in the cockpit.

To facilitate flight with one engine not running, wing span was increased from 27.0 to 29.5 meters (area increased from 117 to 130 sq. meters). Maximum speed was raised to 325 km./hr., and cruising speed to 270 km./hr. Landing speed has dropped from 120 to 110 km./hr. Fuel consumption remains the same, and a range of 5900 km. instead of 5000 km. is obtained. Improvements in design are described in detail and characteristics and performance given for both models. *Luftwissen*, August, 1938, pages 293–294, 3 illus., 1 table. *Aeroplane*, August 17, 1938, page 203, 1 illus.

Blohm and Voss Torpedo Bomber. Blohm and Voss Ha 140 twin-engined twin-float general-purpose seaplane (two 800-hp. B.M.W. 132 9-cylinder engines) can be used for torpedo carrying, bombing, or long-range reconnaissance. Torpedo or bomb load is accommodated internally, being covered during flight by retractable shutters which protect it against spray during take-off. There are two gun positions, the forward being a revolving turret. Aileron control embodies a new rotary system. Maximum speed 199 m.p.h. Cruising speed 183 m.p.h. Maximum range 1553 miles. Gross weight, 18,739 lb. Weight empty 13,889 lb. Short description. *Flight*, Oct. 6, 1938, page 296, 1 illus.

Blohm and Voss Ha 137B Single-Seater Combat Airplane. Single-seater all-metal combat airplane designed for pursuit and dive bombing is powered by a Junkers Jumo 210 640-hp. engine but can be equipped with an air-cooled engine of equivalent power. Equipped as a dive bomber the plane carries 200 kg. of bombs. Maximum speed 340 km./hr. Cruising speed 300 km./hr. Range 600 km. Time to climb to 1000 meters 1 min. 30 sec. Practical ceiling 8500 km. Description, characteristics, performance. *Rev. de l'Armée de l'Air*, August, 1938, pages 939–942, 6 illus., 1 table.

A German Low-Powered Aeroplane. Arado Ar.79 side-by-side two-seater low-wing monoplane for ab initio civil or military training. Hirth HM.504 A.2 four-cylinder inline aircooled 105-hp. engine. Maximum speed 143 m.p.h. Cruising speed 127 m.p.h. Range 636 miles. Description, characteristics, performance. *Aircraft Engg.*, October, 1938, pages 321–322, 3 illus., 1 table.

Germany's Air Arm. Later prototype fighters include the *Messerschmitt Bf.* 110 with two new DB.601 engines of over 1300 hp. each. Speed is supposed to be well over 350 m.p.h. and armament includes shell guns. The Focke Wulf concern is said to have a single-engined pusher type under development. Fighters, dive bombers and flying boats in use in the German Air Force are discussed and illustrated.

The following experimental prototypes are referred to: *Arado* fighter with parasol wings and retractable undercarriage; *Dornier D.19* heavy-bomber monoplane (four Bramo radials) on the lines of the Boeing B-17; *Arado Ar.95* general-purpose twin-float seaplane now on the export market; and a *Henschel* twin-engined fighter monoplane. The *Dornier Do.19* and military versions of the *Junkers Ju. 90* and *Focke-Wulf Condor* were intended to equip bomber squadrons, according to rumor, but that specification was cancelled when General-Major Udet came into office. *Flight*, October 13, 1938, pages 313–315, 11 illus.

The Junkers Ju 90 Air Liner. Low-wing four-engined all-metal 40-passenger airplane. Either aircooled or water-cooled engines each developing from 800 to 1200 hp. and driving three-bladed variable-pitch propellers can be used. Each engine, together with its mounting can be readily removed from the wing for inspection by loosening four ball-type screw connections and only 25 minutes are necessary for removing one engine and replacing it by another. Four Junkers Jumo 211 engines, each giving about 1100 hp. for take-off. Maximum speed 255 m.p.h. Cruising speed 217 m.p.h. Flight with one engine out at 13,100 ft. Flying range (21 to 23 tons total weight) 1243 miles. Long description of design, construction, and equipment. *Engineering*, October 21, 1938, pages 487–488, 12 illus., 4 on sup. plate (XXI).

Gothas—Twenty Years After. F. D. Bradbrooke. Baby *Gotha Go.150* two- or three-seater touring airplane (two 40-hp. Zundapp engines) has a maximum speed of 127 m.p.h., cruising speed of 121 m.p.h. and range of 496 miles. Description of airplane and its flight performance. Reference is made to the Gotha Go.146 single-seater racer-trainer (two 240-hp. Hirth engines, 186-m.p.h. cruising speed) and both the Go.146 and Go.150 are compared with the Percival Q.6. *Aeroplane*, September 14, 1938, pages 323–324, 2 illus., 1 table.

The Siebel-Halle Hallore Light Twin-Engined Airplane. A. Frachet. Siebel-Halle Fh.104 Hallore which attracted attention at the Third Licteur Rally is equipped and arranged like the larger commercial transports and may be used for transporting passengers and mail, for training military pilots, or for touring. Powered by two Hirth H.M.508-H 240-hp. 8-cylinder Vee aircooled engines, the airplane transports five passengers over 950 km. at an average speed of 300 km./hr. Maximum speed 335 km./hr. Long description. *Les Ailes*, September 29, 1938, page 9, 3 illus., 1 table.

GREAT BRITAIN

Britain's Fighters. Hawker Hurricane has a maximum speed of 335 m.p.h. and carries eight Browning machine guns mounted in the wings. Both Hurricane and Spitfire are powered by Rolls Royce Merlin II 1050-hp. engines. "No other nation has such an advanced liquid-cooled unit in service." Photographs of both fighters and of six R.A.F. bombers (Bristol Blenheim, "still the fastest twin-engined bomber in standard use in any air force," Fairey Battle, Handley-Page Hampden and Harrow, Armstrong-Whitworth Whitley, and Vickers Wellington) as well as of the Avro Anson general reconnaissance monoplanes and Vickers Vildebeest torpedo bombers for coastal defence. *Flight*, October 6, 1938, pages 302a–302d, 10 illus.

Foreign News in Brief. Hawker Hurricane 8-gun monoplane fighter which made the 327-mile flight from Edinburgh to London in 48 min. When powered with a Rolls Royce Merlin 990–1050 hp. liquid-cooled 12-cylinder engine the Hurricane cruises at more than 300 m.p.h. and has a top speed of about 360 m.p.h. Short description. *Aero Digest*, October, 1938, page 32.

Long-Range Formation. Four Wellesleys of the Long-Range Development Flight were flown 4300 miles from Cranwell to Ismailia in 32 hours at an average ground speed of 135 m.p.h. and at an average height of 10,000 ft. A few details of flight and references to changes made from the standard Wellesleys in service. *Flight*, July 14, 1938, page 42, 3 illus.

British Light Airplanes. Taylor-Watkinson single-seater low-wing monoplane suitable for post-graduate flying by Civil Air Guard pupils. Maximum speed 90 m.p.h. Brief note on safety features and ingenious water-cooling system with automatic temperature control. *Flight*, August 25, 1938, page 166, 1 illus.

Luton Major two-seater described. *Flight*, August 25, 1938, page 168h, 1 illus.

Open two-seater version of the Mosscraft training monoplane (95-hp. Pobjoy Niagara III engine, maximum speed 140 m.p.h.). Few details. *Aeroplane*, October 5, 1938, page 416, 2 illus.

Tipsy two-seater airplane designed for easy maintenance and quantity production. Structural details. *Flight*, October 6, 1938, page 301, 7 illus.

Wicko cabin two-seater monoplane (130-hp. Gipsy Major engine, maximum speed 140 m.p.h., cruising range 480 miles). Details of this and other airplanes previously designed by G. N. Wickner. *Aeroplane*, October 5, 1938, pages 413–414, 7 illus.

Another Atlantic Phase. Test flights have shown that the range of the Albatross is 3180 miles in still air at a cruising speed of 212 m.p.h. The airplane will have ample reserve for any but the most exceptional conditions when carrying the stipulated 1000 lb. of mail and crew of four. The particular interest of the airplane for Atlantic work is that of discovering whether winter flying can be continued over the northern route. Brief note. *Flight*, October 13, 1938, page 324.

The Fastest King's Cup. Design and equipment of the Special Percival Mew Gull (D.H. Gipsy Six R engine) in which A. Henshaw won the King's Cup Race at 236.25 m.p.h. after covering 1012 miles in 4 hr. 16 min. 59 sec. Brief description in a long account of the race illustrated by photographs and drawings of details of some of the airplanes participating. *Flight*, July 7, 1938, pages 4–11, 23 illus., 2 tables.

Getting Out the Big Stuff. Three landplanes each weighing 31.7 tons fully loaded (four 1375-hp. Bristol Hercules 14-cylinder radial sleeve-valve engines) are being built by Short Brothers. Two are designed to operate at 10,000 ft. with a payload of 18 passengers and 3000 lb mail and freight. The third will be an experiment in substratosphere flight having a pressure cabin and a normal operating height between 20,000 and 25,000 ft. This indicates the use of two-speed superchargers. Bristol Hercules H.E. (1SM) engines with two-speed superchargers are about to be type tested. The high-flying version has an estimated cruising speed of 250 m.p.h., and all three will have ranges of about 3000 miles against a 30-m.p.h. head wind.

Few details of these landplanes and of the C Class Development flying boats on which the company is also working. They are derived from the C Class Empire flying boats, and are to have an all-up loaded weight of 74,000 lb. and four 1375-hp. Bristol Hercules engines. Mention is also made of the Short modified C Class flying boats arranged for refueling in the air to a maximum weight of 53,000 lb., DeHavilland D.H.95 transports, and Armstrong-Whitworth Ensigns and DeHavilland Albatross. Short article. *Aeroplane*, October 12, 1938, page 446.

Brief description and editorial. *Flight*, October 13, 1938, pages 328 and 312.

The Latest. New data on the following new military and civil aircraft: Hawker Hurricane eight-gun fighter (maximum speed 335 m.p.h. at 17,500 ft., climb to 20,000 ft. in 9 min., landing speed 62 m.p.h.). Armstrong Whitworth Whitley III A.W. 38 bomber (two Tiger VIII engines, cruising consumption for 1000 hp. at 15,000 ft. 65 gal./hr., weight loaded 24,000 lb., wing loading 19.45 lb./sq. ft., top speed 215 m.p.h. at 15,000 ft., cruising speed 177 m.p.h. at 15,000 ft., cruising range 1315 miles). Ensign four-engined airliner (top speed 205 m.p.h. at 7000 ft., cruising 170 m.p.h. at same height, cruising range 850 miles).

Other performance figures for the Whitley and Ensign, as well as references to several light planes, and to performance data on the new Bristol Aquila IV, two-speed supercharged Pegasus XVII and XVIII, and on the Alvis Leonides. *Flight*, October 20, 1938, page 334.

Seaplane Distance Record for Britain. Short-Mayo Mercury's 6045-mile nonstop flight from Dunde, Scotland, to Orange River, South Africa. Power loading of the Mercury at the moment of separation of the two components (2135 gal. gasoline in the tubular spar and float tanks) was about 20 lb./hp. and wing loading about 45 lb./sq.ft. Separation took place at 4700 ft. Seaplane was powered by four Napier Rapier 16-cylinder 329-hp. engines. Account of the flight, radio preparations, and working stations on the route. Editorial comments on the fuel consumption which averaged about 50 gal./hr. and on the loaded weight which was 27,500 lb. instead of 20,800 lb. *Flight*, October 13, 1938, pages 321–322, 311.

South with a Hurricane. Details of flight made on February 10 by Squadron Leader J. W. Gillan in a Hawker Hurricane single-seater fighter (1030-hp. Rolls Royce Merlin II engine) over 327 miles at an average speed of 456 m.p.h. with a strong tail wind. Performance figures of the Hurricane also given. Abstract from Journal of the Royal Air Force College. *Aeroplane*, October 12, 1938, page 446, 1 table.

HOLLAND

The Koolhoven F.K.55. Single-seat fighter monoplane having oppositely-rotated propellers, ailerons of high aspect ratio, undercarriage retracting into fuselage, and split flap. Armament consists of one cannon in front of pilot to fire through the hollow propeller shaft, four fixed machine guns in the wings, and 500 rounds of ammunition for each gun. Lorraine Sterna 12-cylinder 60-degree-vee vertical water-cooled supercharged engine. Maximum speed 317 m.p.h. at 11,810 ft. Cruising speed 280 m.p.h. at 11,810 ft. Maximum range 621 miles. Details of design, characteristics, performance. *Aeroplane*, August 17, 1938, page 204, 2 illus., 1 table.

A 300 M.P.H. Koolhoven Fighter. Koolhoven F.K.58 Single-seater fighter monoplane (1080-hp. Hispano-Suiza two-row radial engine) has been offered to the French government and has been tested in France. Four fixed machine guns mounted beneath the wing outboard of the propeller are fired hydraulically. Gilled cowling forms a fairing for the wheels when retracted. Top speed 300 m.p.h. at 14,740 ft. Cruising speed 268 m.p.h. Range 530 miles. *Flight*, October 6, 1938, page 298, 3 illus.

Koolhoven FK-49 Photographic Plane. Model FK-49 photographic twin-engined full-cantilever monoplane of mixed construction. In addition to the pilot's compartment and cabin there is a dark room aft. Suitable openings provided in the cabin floor for aerial photographic work permit the use of a viewfinder, drift indicator and cameras. Two Ranger V-770B4 305-hp. engines. Maximum speed 165.7 m.p.h. Cruising speed 149.1 m.p.h. Absolute ceiling 23,951 ft. Cruising range 472 to 621 miles. *Aero Digest*, October, 1938, page 95, 4 illus.

A Long-Range Tourer. Koolhoven FK-57 four-passenger gull-wing monoplane (two Series II Gipsy Six engines) designed to a special order. Top speed 178 m.p.h. Cruising speed 168 m.p.h. at 6000 ft. Normal range 900 miles. Range with extra tanks 1245 miles. Few details. *Flight*, October 6, 1938, pages 302, 300, 1 illus.

HUNGARY

Re-Birth in Hungary. M.19 two-seater tandem low-wing cabin monoplane. Gipsy Major 130-hp. engine. Maximum speed 149 m.p.h. Cruising speed 137 m.p.h.

M.21 single-seater open biplane designed for aerobatics. Siemens SH.14-A 160-hp. engine. Maximum speed 137 m.p.h. Cruising speed 109 m.p.h. Characteristics and performance of these airplanes which are manufactured at the Budapest Technical University. *Aeroplane*, October 5, 1938, page 417, 2 illus.

ITALY

Italian Airplanes. Saiman LB2 two-seater touring airplane. Alfa-Romeo 110 130-hp. 4-cylinder inline inverted engine driving a pusher propeller. Top speed 215 km./hr. Cruising speed 190 km./hr. Range 3.5 hours.

Cant Z.1012 airplane for touring or feeder-transport service carries a pilot and three passengers. Three Alfa-Romeo 110 120-hp. 4-cylinder inverted inline aircooled engines, or three Alfa-Romeo 115 185-hp. 6-cylinder inverted inline engines. Top speed with the latter engines 320 km./hr. Range 1000 km. Performance given for airplane with both engines. Short descriptions, characteristics, and performance of both Saiman and Cant airplanes. *Luftwissen*, August, 1938, pages 301–302, 3 illus., 2 tables.

The Fiat G.50 Single-seater low-wing cantilever monoplane fighter having split flaps, inward-retracting undercarriage and four fixed machine guns (two in the top decking of fuselage to fire forward through propeller disk and two in leading edges of the wings). Bomb load up to 36 bombs of 6.614 lb. each or 144 bombs of 2.205 lb. each. Fiat A.74 R.C.-38 14-cylinder two-row radial supercharged 840-hp. engine. Maximum speed 299 m.p.h. at 14,760 ft. Cruising speed 261 m.p.h. at 14,760 ft. Range at 70 per cent power 435 miles. Details of design, characteristics, performance. *Aeroplane*, August 17, 1938, page 204, 2 illus., 1 table.

JUGOSLAVIA

Rogojarsky S.I.M. VI-A and XI Airplanes. A. Frachet. Development of the Jugoslavian aircraft industry, and descriptions of the Rogojarsky S.I.M. VI-A two-seater sport monoplane (Walter Mikron 60-hp. engine, maximum speed 160 km./hr.) and the S.I.M. XI single-seater monoplane for training and aerobatics (Bramo S.M.-14a 145–160-hp. engine, maximum speed 200 km./hr.). *Les Ailes*, September 22, 1938, page 9, 4 illus., 4 tables.

POLAND

PZL Wicher. Low-wing transport for 14 passengers and crew of four. Two Wright Cyclone QR 1820 Q2 1000-hp. engines. Top speed 377 km./hr. at 2000 meters. Range 1840 km. *Luftwissen*, August, 1938, pages 302–303, 3 illus. *Aeroplane*, August 17, 1938, page 205, 2 illus.

U. S. A.

American Export Airlines Buys Ocean Survey Plane. Consolidated long-range flying boat has been purchased by American Export Airlines for making survey flights preparatory to regular scheduled service from New York to principal European countries, North Africa and Asia Minor. Survey ship is a twin-engined semicantilever monoplane with a maximum speed of 200 m.p.h. at 8000 ft. Cruising range is about 4000 miles with a payload of 2000 lb. and a crew of six. Few details. *Aero Digest*, October, 1938, page 24.

British Airways' Lockheed Fourteens. Special modifications made in the Lockheed 14 airplanes (two Wright Cyclone F.62 engines blown and geared to a ratio of 16:11) to fit them for the European and West African services of British Airways. Radio equipment carried and remarkable long-range performance are also described. Special radio compartment showing location of radio equipment, graph giving block-to-block speeds and times for different trip lengths, and details of the operation of the Fowler flaps are illustrated. *Flight*, October 6, 1938, pages 294–296, 4 illus., 1 table.

Comments on the Lockheed 14s used by the Dutch K.L.M. Airways, and an account of flights in these airplanes. These Lockheeds are said to have many features in common with those which are to be used on British Airways. *Flight*, August 18, 1938, pages 138–140, 5 illus.

Cessna Airmaster for 1939. Four-passenger high-wing monoplane having a split-type flap located between aileron and fuselage. Actuated electrically the flap stops automatically in the fully extended position and can also be lowered to any increment of the full-down position by the pilot. Warner Super Scarab 145-hp. engine. Maximum speed 162 m.p.h. Cruising speed 143 m.p.h. Cruising range 525–785 miles. Description. *Aviation*, October, 1938, pages 42, 45, 4 illus., 1 table.

Men with Very, Very Small Wings. C. F. McReynolds. Of the racers at Cleveland the new Chester Goon is considered outstanding on the basis of efficiency with a rating of 172.4, and next comes the Schoenfeldt Firecracker. Hughes racer achieved a figure of 188.4, probably the highest landplane figure established. Mr. Smoothie, the Conqueror-powered racer that did not race, shows a purely theoretical factor of 185. Table shows progress in relative speed efficiency of representative race planes compared with the first Wright Pusher. The various designs are discussed and predictions made for new developments between now and the 1939 National. *Aviation*, October, 1938, pages 20–21, 70, 3 illus., 2 tables.

Roscoe Turner's Laird L-RT Racer. Midwing monoplane, winner in the Thompson Trophy Race, is powered by a Twin Wasp engine rated at 1000 hp. Wing span 25 ft. Wing loading 51.8 lb./sq. ft. Maximum speed 330 m.p.h. Landing speed 87 m.p.h. Description. *Aero Digest*, October, 1938, page 80, 2 illus., 1 table.

The Wright-Powered Brewster Model 138 Military 2-Seater. Brewster all-metal two-place midwing airplane is an export version of a Navy scout bomber and is adaptable to use as a fighter, bomber or scout airplane. Bombs are carried in the fuselage and released through an opening in the bottom, normally closed by sliding doors. Fixed machine guns are also carried in addition to a flexible gun in the rear cockpit. Wright G series Cyclone engine rated at 950 hp. at 2200 r.p.m. for take-off and 750 hp. at 2100 r.p.m. at 15,200 ft. Description of construction but no performance figures. *Aero Digest*, October, 1938, pages 71, 72, 6 illus.

Vega Building First Model. Vega 5–6 place monoplane will have a retractable tricycle landing gear and a Unitwin engine installation, consisting of two 260-hp. Menasco engines, mounted side-by-side, driving a single constant-speed propeller through a new method of gearing which embodies overrunning clutches operating on the same plan as the automobile overdrive. Short description. *Aero Digest*, October, 1938, pages 20–21, 1 illus.

Light Airplanes. Aeronca Chief Model 50 powered with a 50-hp. Continental, Franklin, Lycoming or Menasco engine. Maximum speed 100 m.p.h. Cruising speed 90 m.p.h. Cruising range 250 miles. Description. *Aero Digest*, October, 1938, page 87, 4 illus., 1 table. *Aviation*, October, 1938, page 46, 2 illus., 1 table.

Beco L-5 two-place high-wing sport and training monoplane using Handley-Page slots and flaps. Lambert 90-hp. engine. Maximum speed 120 m.p.h. Cruising speed 100 m.p.h. Range 500 miles on 25 gal. of fuel. Few details. *Aero Digest*, October, 1938, page 22, 1 illus.

Luscombe Fifty two-seater all-metal high-wing monoplane. Continental A-50 engine. Maximum speed 103 m.p.h. Cruising speed 94 m.p.h. Few details, characteristics, performance. *Aviation*, October, 1938, pages 44–45, 9 illus., 1 table.

Piper Cub Coupe high-wing monoplane. Continental A-50 engine. Description but no performance figures. *Aero Digest*, October, 1938, page 79, 1 illus. *Aviation*, October, 1938, page 41, 2 illus.

Private Fighter. Comments on Major A. J. Williams' Grumman G-22 Gulfhawk biplane from the British point of view. Reference is made to the Grumman XF_4F-2 airplane designed to supersede the U.S. Navy F_3F-2, the former being a midwing monoplane powered with a Wasp 1000-hp. engine and considered capable of over 300 m.p.h. *Flight*, July 7, 1938, pages 22–23, 4 illus.

U. S. S. R.

Russian Stratoliners? Type 20B special aircraft for high-altitude work are now in the course of construction at the Moscow aircraft works. Type was designed by M. Jumashef who made the North Pole flight to America, and is intended for operation at an altitude of 5–6 miles. It is fitted with special de-icing equipment in which field sensational inventions are said to have been made in Soviet Russia of late. Jumashef has made a nonstop flight in one of the machines from Moscow to the Ural mountains and back. A crew of eight was carried at a cruising speed of 215 m.p.h. at 16,500 ft. Nonstop flight from Moscow to California and back is planned. Brief reference. *Flight*, August 18, 1938, page 156.

Aircraft Accidents

Two British Official Accident Reports. Accident to a DeHavilland Dragon which occurred at Land's End when the pilot was attempting to land under conditions of bad visibility is attributed to error of judgment on the part of the pilot. Brief note.

Accident to the Cygnus flying boat of Imperial Airways at Brindisi is considered to be due to the incorrect setting of the flaps during take-off. Short review of conclusions. *Aircraft Engg.*, October, 1938, page 305.

Air Transportation

Berlin to New York Non-Stop. First transatlantic crossings to be made by a landplane and organized by a regular airline company, was accomplished by the Focke-Wulf F.W.200 Condor Brandenburg (four 720-hp. B.M.W.132 Dc engines). A distance of 3980 miles was covered at an average speed of 159 m.p.h. Normal all-up weight of the Condor is about 14 tons whereas weight at take-off was 18 tons. Details of flight. *Aeroplane*, August 17, 1938, page 208.

3,000,000 Miles in N. Z. Development of the New Zealand airlines and their equipment. *Flight*, September, 1938, pages 281–282, 4 illus.

Air Transportation Makes Its Contribution to Our National Economy. Air transport statistics are illustrated and discussed. *Aviation*, October, 1938, pages 32–34, 4 illus.

Atlantic Survey Flights Continue. Initial survey crossing of the North Atlantic by Air France was made August 31, when the Latecoère 6-engined flying boat Lieutenant-de-Vaisseau-Paris landed at Port Washington after a 22-hr. 48-min. flight from Horta at an average speed of 112 m.p.h. German catapult service between the Azores and New York was stepped up by Nordstern, newest of the four-engined Ha-139 seaplanes, when she completed a 2397-mile flight in 13 hr. 35 min., averaging 176 m.p.h. compared with the 157 m.p.h. of her sister ships. Brief note. *Aero Digest*, October, 1938, page 21, 2 illus.

News of transatlantic progress, and references to new German transports and Diesels, the British Mercury, and new air-transport lines abroad. *Aviation*, October, 1938, pages 53 and 63, 2 illus.

Australia's Airlines. H. F. King. Scheme for distributing the mail brought to Australia by the Empire flying boats, and flying impressions, ground organization, and radio equipment and stations in Australia. *Flight*, September 29, 1938, pages 270–271, 6 illus., 2 tables.

Australia's Future Development. Every capital city is connected by daily airline service except Perth which is served thrice weekly and an ever-increasing number of country towns are being linked with their state capitals by feeder services. Probable line of future development is in the backblocks. *Aeroplane*, September 28, 1938, page 389.

Blazing a Trail for Transatlantic Air Travel. Cy Caldwell. Regular passenger and mail service between the United States and Europe will open

with the delivery of the big 41½-ton Boeing Clippers now undergoing tests. It is expected that Imperial's transatlantic ships will be modified Short Empire boats of more than 25 tons. Criticism of the Short-Mayo Composite aircraft (upper component Mercury being considered as scarcely a commercial probability for transatlantic travel), and of the German catapulted airplanes. Flight to Bermuda is described. *Aero Digest*, October, 1938, pages 58–59, 84, 6 illus.

Nineteen Years of Australian Aviation. R. G. Lloyd Thomas. Development of aviation in Australia and map of Australian air services. *Aeroplane*, September 28, 1938, pages 371–374, 7 illus.

Pan American Airways' New Transpacific Operations Base. Pan American Airways' new base lying just north of Yerba Buena Island on San Francisco Bay, includes a substantial portion of Treasure Cove, the seaplane basin at the southerly margin of the island. Description of buildings and landing areas. *Aero Digest*, October, 1938, page 55, 2 illus.

Airships

Is There a Future for Airships? Military value of airships is greater for the United States than for any European country, for the airship, loaded with fighting planes, is essentially a long-distance and ocean-defending weapon. One surface carrier with its full aircraft complement could hardly hope to cope successfully with twenty dirigibles and their aircraft complements. Short editorial. *Aero Digest*, October, 1938, page 64.

Airship Mooring in England. The Barrow system with rigid masts. Short note only. Continued. *Airship*, July-September, 1938, page 16, 1 illus.

Lighter than Air in the U. S. A. Lord Ventry. Airship activities of the U.S. Army and Navy. References are made to the work of the Army T.C.13 and the C.6 motorized balloon. Discussion of the Navy's airship activities cover: the old Los Angeles; mooring masts used; five airships compared to British wartime standards; controls; helium; value of non-rigids; the Z.M.C.-2 metal-clad and a new one reported ordered. Goodyear airship activities are also taken up, those of the Enterprise in particular. Table of airships in the United States, May, 1938, included. *Airship*, July–September, 1938, pages 17–23, 8 illus., 1 table.

Balloons

The Balloon Demonstration. In the recent display of 25 barrage balloons over London five broke loose and their trailing cables did a certain amount of damage to chimney pots and tiles and to an electric railway. Four were captured but one went out to sea and sank near the coast of Denmark. In one case the cable was allowed to run off the winch, and in most of the other cases a jerk in transferring the strain from the landing ropes to the winch cable seems to have caused failure. Brief editorial. *Flight*, October 13, 1938, page 312.

Barrage Balloons. Technical problems are considered in regard to performance and properties required of a barrage balloon, to the question of spherical or elongated balloons, balloons with an air chamber, or dilatable balloons, and to the effect which balloon ground cables would have on an airplane. Discussion also covers: principal characteristics of the Ariel balloon, winches for balloons, gases used in inflating balloons, and tactical purposes of balloons in large areas, long narrow areas and at certain spots are discussed. From "Bulletin Belge des Sciences Militaires," April. *Luftwehr*, August, 1938, pages 332–336, 9 illus.

A Flight of 29 Hours with a Balloon of 457 Cu. Meters and Carrying Two Pilots. Soviet balloon of 457 cu. meters piloted by Zykov and Egorov is said to have made a flight from Moscow to Chepetovka remaining in the air for 29 hours 45 minutes, which would be a quadruplicate record of duration, beating those attained by larger balloons. Balloon records in different categories are discussed. *Les Ailes*, September 29, 1938, page 10.

Gordon-Bennett Balloon Race Was Won by Janusz, the Polish Pilot. Polish L.O.P.P. balloon piloted by Janusz and Janisz landed in Bulgaria 1650 km. from the start at Liège, winning first place. Second place was won by the Polish Warsawa-II piloted by Kryszowski and Lancucki and landing in Rumania 1470 km. away. Third place was won by the Belgian SII piloted by Thonnard and Vanderschueren covering 1450 km. and landing in Bulgaria. List of race results. *Les Ailes*, September 22, 1938, page 4.

Gliders

National Gliding Contests. Account of contests organized by the British Gliding Association. *Flight*, July 21, 1938, pages 54–57, 11 illus.

Sailplane Cloud-Flying. P. Wills. Finer points of blind flying in sailplanes, and differences in technique which the pilot must learn. *Flight*, July 14, 1938, pages 40b–40c and 40h, 3 illus.

The Four Winds. A train of no fewer than nine gliders was towed by an airplane at a Moscow Aviation Day celebration, according to reports. Brief reference. *Flight*, October 20, 1938, page 335.

Soaring—A New Pastime for Officers of the Royal Air Force. Squadron-Leader G. M. Buxton. The modern sailplane; world records of today; hill soaring; soaring on a cold front; thermal soaring; a criterion for good soaring weather; cloud flying; the value of soaring technique to an Air Force officer; need for clubs and part that an R.A.F. officer can take in a club; and practical success of a club organization. *R.A.F. Quarterly*, October, 1938, pages 386–391.

Propellers

On Airscrews, Oppositely-Rotating and Otherwise. Problem of the effect of the torque on the airplane and of increase of propeller diameter with power; use of oppositely-rotating propellers on the new Koolhoven fighter; use of two coupled Fiat engines on the Italian Macchi-Castoldi racer holding the absolute speed record of 440 m.p.h.; Dr. Weinig's opinion that close-coupled tandem arrangement of oppositely-rotating propellers would increase the speed of a single-seater fighter by some 25 m.p.h. over the equivalent with two engines; question of using controllable-pitch propellers in such combination; and Menasco-Lockheed Unitwin installation. *Aeroplane*, August 17, 1938, pages 201–203, 3 illus.

Modern Variable-Pitch Airscrews. Detailed descriptions of the Rotol hydraulically-operated constant-speed propeller of the non-feathering type, the DeHavilland-Hamilton Standard Hydromatic quick-feathering propeller, and the Ratier electric two- and three-bladed propellers for single-engined airplanes. In the description of the D.H.-Hamilton propeller reference is made to a collar of plastic material located between roller-bearing race and fillet of the blade-retaining shoulder, a modification first introduced by the DeHavilland Company on their British-built models. Descriptions are illustrated by photographs and drawings of the propeller parts, one drawing showing the installation of the Ratier propeller as adapted to a Morane-Saulnier single-seater fighter with a Hispano-Suiza engine cannon. *Aircraft Engg.*, October, 1938, pages 306–312, 14 illus.

Increasing Airscrew Production. New resin finish used by the Hordern-Richmond Company in the manufacture of wooden propeller blades was developed by the B.T.H. company and has been accepted by the British Air Ministry as an alternative to the Schwarz finish. Company uses birch for propeller blades as this was considered after tests at Farnborough as a suitable and much more easily obtainable substitute for mahogany and walnut. Process used in Hordern-Richmond factory for making propellers briefly described. *Flight*, August 25, 1938, page 168h.

Schwarz VP 1/II Variable-Pitch Propeller. Description of the Schwarz variable-pitch propeller with two blade settings both operating automatically. Drawings illustrate the details of the hub and blade-setting apparatus. *Luftwissen*, August, 1938, pages 303–304, 4 illus.

Silencing of Propellers by Thrust Relief. M. M. Munk. Aircraft propeller noises can be materially reduced by thrust relief which imparts the further advantage of improved air feed with which it is always associated. Propeller is relieved by a portion of total thrust (20 per cent or more), this thrust being produced probably by a stationary ring surrounding the propeller and having a section contour with its pressure side radially outside and its suction side radially inside. Trailing edge would flare to the rear. Advantages of thrust relief, magnitude of the relief, effect on slipstream loss, application to small aircraft, and smaller diameter selected for the propeller are discussed. *Aero Digest*, October, 1938, pages 67, 79, 2 illus.

Miscellaneous

The First Maneuvers in Leaving and Climbing up to an Autogiro in Flight E. Donois. Experiences of the author in which he descended to the ground from an autogiro in flight by climbing down a rope which is said to be much less fatiguing than a parachute descent. *Rev. de l'Armée de l'Air*, August 1938, pages 900–904, 4 illus.

Problem of Flight in Bad Weather and Icing Dangers. H. Heintz. Comments from the pilot's point of view on the problem of landing an airplane in ground fog and flying during electrical storms, and a discussion of the icing dangers. *Luftwissen*, August, 1938, pages 275–277.

Records Recognised. New World's Records homologated by the F.A.I. Distance in a Closed Circuit of 7240 miles at an average of 116 m.p.h.—Japanese Kôkeu monoplane (700-hp. Kawasaki 12-cylinder vee engine). Speed record of 394.166 m.p.h. over a 100-km. course—General-Major E. Udet in a Heinkel He-112-U single-seater fighter (Mercedes-Benz DB-601 12-cylinder inverted-vee engine of 1360 hp.). Seaplane Distance Record of 5214.789 miles in a straight line and 5241.309 miles in a broken line—Dornier Do.18 flying boat (two Junkers Jumo 205 heavy-oil engines). Four records held by Flying-Officer A. E. Clouston and V. Ricketts for their flight from England to New Zealand and back in the DeHavilland Comet.

Of the 180 International and World's Records recognized for all types of aircraft France holds 53, Italy 34, Germany 22, Russia 18, U. S. A. 17, Czechoslovakia 14, Great Britain 10, Poland 7, Japan 8 and Belgium 3. Brief note. *Aeroplane*, August 17, 1938, page 193.

Aircraft Instruments

Simplified Instrument. Sperry Flightray combines the more essential indications on the face of a single indicator. It uses a cathode-ray tube as the indicator upon the luminous screen on which various indications are assembled in a standard pattern, and reproduces indications from the artificial horizon, directional gyro, turn indicator and altimeter. In addition, it may be used to show position on the glide path and localizer radio beam for instrument landing. Brief reference. *Aero Digest*, October, 1938, page 22.

Three-Axis Angular Velocity Recorder of the D.V.L. W. Lieve. Angular velocity in three components vertical to each other is recorded on a time basis with the D.V.L. measuring apparatus. Instrument was developed in collaboration with Kreiselgeraete G.m.b.H., and thorough flight tests have demonstrated that it meets the requirements of flight measurement. As a measuring element for each single component of the angular velocity, the gyroscopic couple is used. All axes move in roller bearings. Gyro turn is so large, compared with the friction moment, that the apparatus responds to an angular velocity of $\omega = 0.005\ (s^{-1})$. Description of recorder. *Luftwissen*, August, 1938, pages 297–298, 3 illus., equations.

Miscellaneous Equipment

Parachutes. N. Ewart. Various types of Irvin parachutes used by R.A.F. pilots on different duties are briefly described including the seat pack, the two-point quick-connector, the training and the chair types, and the automatically-operated parachute for balloon occupants. The G.G. equipment described covers the Harnasuit, the improved Parasuit (used by any single occupant of an aircraft whether he be pilot or gunner, and weighing 22 lb. including lifebuoy) and a special parachute for use in gliders. A few details of the "Universal" parachute, a new development of the PAK Parachute Company, which can be used to suit all duties are also given. Two pages are devoted to the use and design of parachutes and to some practical points for those who may have to use them. *Flight*, August 25, 1938, pages 168a–168d, 4 illus.

The Ice Problem. British Air Navigation directions are to be amended so that approved deicing equipment will be compulsory for all public transport aircraft. Equipment must be applied to leading edges of wings, tail surfaces and control surfaces. Dunlop and Goodrich attachments and certain kinds of deicing paste are approved. Short note. *Aeroplane*, October 19, 1938, page 479.

Airport Equipment

Adequate Airport Lighting. W. A. Pennow. Method of estimating lighting equipment which will be necessary for an airport. Diagram of a series contact light and its installation is given and other equipment is illustrated and described. *Aero Digest*, October, 1938, pages 50–51, 123, 5 illus.

Contact Lights for Runways. Westinghouse incandescent contact lights give more clearly defined runways and are installed with the head projecting not more than 2 in. above the normal adjacent grade level. Few details. *Aero Digest*, October, 1938, pages 89, 91.

Testing Apparatus

An Indexed Bibliography of Electron Tubes and Their Applications. E. D. McArthur. Fundamental phenomena; high-vacuum tubes; gas- or vapor-filled tubes; photoelectric tubes; special tubes; rectifiers, amplifiers, inverters, and oscillators; measuring devices; process control; and special ap-

plications. Classified references to literature. *General Electric Rev.*, October, 1938, pages 455–460.

The Month's New Instruments. New devices for measurement, inspection, testing, metering and automatic control. Brief descriptions. *Instruments*, September, 1938, pages 210–216, 25 illus.

Discharge Rates from Gas Flowmeters. J. C. Whitwell. New method of plotting discharge flow rates for instruments of the Venturi and orifice types against differential manometer reading. Groups to be plotted are so calculated by rearrangement of terms of well-known equations that one line on such a plot will be universal for varying values of inlet pressure and temperature. Plate and nozzle orifices, Venturi tubes and long-tube capillary orifices are included, the last being studied in both viscous and turbulent flow ranges for the gas in the capillary. Experimental confirmation also given. *Industrial and Engineering Chemistry, Ind. Ed.*, October, 1938, pages 1157–1162, 4 illus., 1 table, 25 equations.

The Measuring Strength of Indicators. Berndt. Measuring strength of various types of indicators; friction and measuring-strength variations; effect on measuring strength of Hooke's law of compression and Hertz's law of flattening; bending up of the support; and deflection of the pin for rotating and control tests. *Zeit. Instrumentienkunde*, October, 1938, pages 389–408, 20 illus., 3 tables, many illus.

New Instruments and Tools (British). Cambridge snap pyrometer; Griffin and Tatlock continuous gas indicator; Sullivan dial pattern wheatstone bridge; G.E. thermionic tubes and a cathode-ray tube monitor; Negretti and Zambra interrupter for electric contact control; and Zeiss spectroscope for analysis of iron alloys and steels. Short descriptions. *Jour. Scientific Instruments*, August, 1938, pages 277–282, 6 illus.

Metals

Investigation of the Adaptability of Heat-Resistant Materials for Internal Combustion Engines. F. Bollenrath, H. Cornelius, and W. Bungardt. German commercial heat-resistant materials and experimental alloys were investigated to determine their adaptability for blades of exhaust-gas turbines and other parts of aircraft engines exposed to the combustion process. Properties investigated include behavior at loads above resistance to deformation, specific weight and thermal expansion, resistance to temperature changes, and stability of the structure of the metal. Scaling resistance in combustion gases of benzene with and without addition of ethyl fluid was determined. Krupp, D.V.L., Boehler, D.E.W. and Heraeus ferrous alloys were investigated. To be continued. *Luftfahrtforschung*, September 10, 1938, pages 468–480, 62 illus., 7 tables.

Bearings

Metals and Lubricants for Bearings and Gears. R. W. Dayton. Extended abstract of 125 papers presented at the Symposium of the British Institution of Mechanical Engineers and covering: fundamentals of modern lubrication; fluid and boundary film friction; high temperatures at rubbing surfaces; copper alloys; journal and thrust bearings; condition of lubricant on journal bearings; tilting pad bearings; rubber as a bearing material; and causes of cracking. *Metals and Alloys*, September, 1938, pages 211–218, 7 illus.

Corrosion and Protective Coatings

Frettage Corrosion. Results so far obtained by the National Physical Laboratory in research on frettage corrosion. This type of surface deterioration has been noticed between closely fitted metal parts subjected to vibration and when one component is of ferrous metal or alloy. Test apparatus employed is also briefly discussed. Automobile Engineer, August, 1938, page 278.

To Check Corrosion. New anticorrosive process on the Roval system developed by International Corrodeless, Ltd. Process deposits an alloy on a metal surface by electrolytic means, depending on closing the pores of the metal rather than on a protective layer. Dimensions of part treated are practically unaltered. Few details. *Aeroplane*, October 12, 1938, page 452.

Iron and Steel

Defects in Steel. J. A. Duma. Stainless steels, especially those of the 18-8 variety, more conspicuously than any other, are prone to failure by intergranular corrosion. This form of corrosion is anteceded by intergranular chromium-rich carbide precipitation causing a local depletion of the highly corrosion-resisting chromium. Permanent immunity is secured by alloying stabilizing elements such as titanium, colombium, or tantalum with the metal. Corrodibility tests, season cracking and tests for it, defects due to heat checks, zinc embrittlement, and failure due to absorption of nitrogen when lubrication fails are discussed. *Heat Treating & Forging*, October, 1938, pages 504–506, 2 illus.

Vanadium in Steel and Iron. W. J. Priestley. Manganese-chromium-vanadium steels, special vanadium steels, spring steels, tool steels and vanadium in cast iron, Composition, properties and applications are discussed. *Metals & Alloys*, September, 1938, page 237–241, 5 illus., 6 tables.

Nonferrous Alloys

Aluminum Alloys in Aircraft. Dynamic properties of five aluminum alloys and two magnesium alloys at low temperatures, with special attention to notch-bar impact values and reversed bending fatigue strength over the temperature range 20° to −65° C. Results of these tests taken from article by Bungardt. Also short abstract of article by Mathaes on special light alloys for rivet stock in aircraft construction. Disadvantages of duralumin rivets and results of Heinkel research on aging behavior of copper-magnesium-manganese-aluminum alloys are discussed. Brief abstracts from *Zeitschrift fuer Metallkunde*, July. *Metal Industry*, August 12, 1938, page 156.

The Casting of Aluminum Bronze. H. J. Miller. First issue—General requirements including: alloy compositions and properties; high-tensile alloys; preparation of melts; most suitable forms of copper; use of scrap; addition of aluminum; melting equipment; fluxes and covers; deoxidants; pouring and casting practice; Durville casting; shrinkage and contraction; cavities; and volumetric changes recorded in castings.

Second issue—Sand-casting practice. Third issue—Permanent mold casting. *Metal Industry*, August 12, 19 and 26, 1938, pages 147–152, 175–180 and 199–202, 17 illus., 2 tables.

Roller-Die Process of Metal Forming. L. C. Milburn. Advantage of the roller-die machine is its ability to handle stock of any length in one continuous piece. Experimental work described was carried out at the Curtiss-Wright St. Louis Airplane Division in an effort to produce the long stringers suitable for the structure of transport airplanes. The Curtiss-Wright Model 20 transport has wing members 50 ft. in length in which it was sought to avoid splices. Large hat section of 0.064-in. gauge thickness of 24ST Alclad, fully tempered, was first attempted. Aluminum-alloy problems, working out fairing formulas, question of spring-back, and uniformity of work produced are discussed. *Aero Digest*, October, 1938, pages 52–53, 2 illus., 1 diagram.

New Nickel Alloy. Z nickel alloy has the mechanical properties of steel and corrosion resistance of nickel. It has been produced with a tensile strength as high as 250,000 psi and hardness values as high as 46 Rockwell C. Mechanical property range and physical constants given. *Heat Treating & Forging*, October, 1938, page 507, 2 tables.

Production of Elektron Dies To Be Used in Aircraft Manufacture. O. Oeckl. Steps in production of Elektron dies from the mold to the completed die are discussed. Practice at the Henschel aircraft company. *Luftwissen*, August, 1938, pages 285–288, 9 illus., 1 table.

Welding

Electric Spot Welding of Duralumin Structures for Aircraft. F. H. Hentzen. Parts of duralumin aircraft structures which are spot welded in the German Bayerischen aircraft factory are illustrated and discussed, and results of tests are described. Fatigue test results on various types of spot-welded and riveted joints are compared. *Luftwissen*, August, 1938, pages 279–283, 18 illus., 1 table.

Plastics

Moulded Wood. Advantages of the new Jablo low-temperature setting process. By mixing ingredients of the new chemical glue in a particular proportion, the adhesive can be made in such a way that thermoplastic characteristics remain during the bonding of the compressed material, and the final setting is obtained after either a second or third operation with a maximum temperature of 100° C. New method permits manufacture of long components, such as spars or wing skins, in continuous lengths by repeated and "staggered" pressing operations and heat treatment. Aircraft components made experimentally are shown in drawings and method is briefly discussed. *Flight*, September 29, 1938, page 278, 4 illus.

A Plastic Application. Bakelite Ltd. has brought out a new type of laminated sheet which can be made in a variety of simple sections, corrugations or channels. Typical aircraft applications are coverings for leading edges of wings or control surfaces. Brief reference and photograph. *Aeroplane*, September 14, 1938, page 328, 1 illus.

Testing of Materials

Elastic Properties as a Measure of Hardness. S. R. Williams. Elasticity of volume and of form; Hooke's law; development of the equation for coefficient of rigidity and its practical application. To be continued. *Instruments*, September, 1938, pages 223–225, 3 illus., equations.

Sound Deadening. A. P. Constantine. National Physical Laboratory method and the Barlow bar method for assessing the effectiveness of damping materials. *Automobile Engineer*, September, 1938, pages 345–346, 2 illus.

Meteorology

An Electric Hygrometer and Its Application to Radio-Meteorography. F. W. Dunmore. Development of humidity-indicating device functioning electrically, without moving parts or appreciable lag, and at stratospheric temperatures, and its use in radio-meteorograph balloons. Design details; types of glass dual-coil hygrometer units; characteristics of glass units coated with hygroscopic salts and acids (effect of aging, rapidity of response, determination of temperature correction, and tests at low atmospheric pressures); use of the radio-meteorograph (circuit arrangements, construction details, and receiving apparatus); range expansion; and flight test results. Flight record is shown in which the radio meteorograph unit ascended to 68,000 ft. Long progress report from National Bureau of Standards. *Am. Meteorological Soc., Bul.*, June, 1938, pages 225–243, 16 illus., 1 chart on sup. plate.

Frontal Movements Contrary to Indicated Gradient Flow Produced by Minor Waves. A. K. Showalter. In connection with a study of flood-producing storms (April, 1934) in Oklahoma, a detailed analysis was made of several pressure systems with a front north of the center of lowest pressure apparently moving against the gradient flow. Explanation for the unusual behavior of fronts north of low centers seems to be in the effects of the isallobaric component. This type of storm is considered of great importance not only for flood studies but also for short-period airways forecasting. *Monthly Weather Rev.*, June, 1938, pages 165–173, 14 illus.

A Method for the Investigation of Upper-Air Phenomena and Its Application to Radio Meteorography. H. Diamond, W. S. Hinman, Jr., and F. W. Dunmore. Experimental development of a radio meteorograph for the U.S. Navy for sending down from unmanned balloons information on upper-air pressures, temperatures and humidities. Miniature transmitter employs, an ultra-high-frequency oscillator and a modulating oscillator having its frequency controlled by resistors connected in its grid circuit, modulation frequency being a measure of phenomenon studied. Several phenomena may be measured successively, corresponding resistors being switched into circuit in sequence by an air-pressure-driven switching unit also serving for indicating balloon altitude.

Long detailed description includes: experimental work in development; transmitting circuit; ground-station receiving equipment; measurement of cloud height and thickness; altitude determination; the Navy radio meteorograph; electrical hygrometer; and other applications of the general method. *Proc. Inst. Radio Engrs.*, October, 1938, pages 1235–1265, 17 illus.

On the Origin of Tropical Cyclones with an Analysis of the Caribbean Cyclones of 1935–36. Edna Scofield. Study of data furnished by synoptic weather maps and Pan American Airways' wind-aloft observations for the Gulf of Mexico, West Indies and Caribbean. Comments are made on cyclones and fronts (1935–36), and their bearing on various theories regarding character of the tropical front and origin, structure and life cycle of tropical cyclones is considered. Formation of a Dreimasseneck and the "rolling back" of the Ts inversion are considered of significance in forecasting the development of tropical storms. *Am. Meteorological Soc., Bul.*, June, 1938, pages 244–256, 5 illus., 3 tables.

Progress in Weather Forecasting. W. R. Gregg. Main features of the present program of reorganization of the Weather Bureau designed to bring about improvements in the service, particularly in forecasting. Significance of the radiometeorograph in meteorological service; present trends in development of meteorological service; physical basis of forecasting (adiabatic charts, vertical sections, isentropic charts and practical results); specialization in forecasting (airway, hydrologic and hurricane warning services); and research. *Electrical Engg.*, October, 1938, pages 405–412, 6 illus.

Remarks on Kidson's and Weightman's "The Cyclone Series in the Caribbean Sea, Oct. 17–24, 1935." R. G. Stone. More complete surface reports and mapping for larger world-wide areas, and cooperation between state weather services and other institutes to make selected synoptic and aerial ascents with radio meteorographs in lower latitudes. Recommendations, and discussion of the above and other articles. *Am. Meteorological Soc., Bul.*, June, 1938, pages 256–259.

Engine Design and Research

The Combustion Process in the Compression-Ignition Engine. J. W. Drinkwater. Extent of chemical reactions of the fuel and air at various stages during compression and expansion strokes were determined in an investigation of the combustion process. Percentage volumes of the constituent gases in the engine cylinder at different points in the cycle are shown in curves. Crossley-Ricardo single-cylinder compression-ignition engine fitted with a sampling valve with special operating mechanism was used. Amount of aldehydes found in the Comet type of cylinder head was much less than expected. Test apparatus and procedure, range and conditions of sampling experiments, and estimation of aldehydes and nitrogen peroxide in the Comet chamber gases are discussed in detail. *Instn. Mechanical Engrs., Proc.*, 1938, pages 415–459 and (discussion) 459–493, 49 illus., 18 tables.

Drag of Airplane Radiators, Particularly with Regard to Air Heating (Comparison of Theory and Measurement). B. Goethert. Previous theoretical and experimental investigations on the unheated and heated radiator for aircraft engines are considered in great detail. Test results are compared with the theoretical. Limits for reduction of cooling drag are shown and means are suggested which would make a reduction of cooling drag possible.

Discussion covers: heat transmission and pressure drop of most important radiator blocks (N.K.F., H.W. and Lorenz air-tube and S.K.F. and H.W. water-tube radiators); deviation of designed radiator blocks from ideal block; increase of pressure drop in radiator block by heating; rate of flow through unheated radiator; drag of unheated radiator (calculations and their comparison with measurements); calculated drag compared with measured drag of freely-exposed radiators with equal radiator frontal area; required enlargement of nozzle opening for the heated radiator at equal rate of flow, and rate of flow return by heating at equal nozzle opening; cooling drag calculations and their comparison with measurements of freely-exposed radiators and with radiator computations by Weise for severe heating; calculations and measurements of installed radiators; effect of radiator outflow on fuselage drag; pressure distribution changes due to the mixing of air moving out of radiator with free flow; and minimum drag of the complete airplane compared with actual drag of the radiator. Long article. D.V.L. Report. *Luftfahrtforschung*, September 10, 1938, pages 427–444, 24 illus., 3 tables, 8 equations.

The Air-Cooled Cylinder. Survey of aircraft-engine cylinder designs in use, and suggestions regarding their design. Barrel should be made of such proportions as to be capable of withstanding all internal-pressure conditions without reinforcement by the cylinder-head assembly and without expansion under those pressure conditions sufficient to destroy continuity of the inner hardened surface. Seal and thread-engaging surfaces should be truly normal to cylinder axis. Cylinder base must be stiff, truly normal and with as many holding points as possible close up to the wall. Temperature equalization should be secured by means of fin drilling in location of the higher temperatures. Thread should be as short as possible with due strength and head should be treated as an entirely separate unit. A trapped uncrushed gasket should be employed for sealing. *Automobile Engineer*, July, 1938, pages 257–258, 4 illus.

Cylinder Wear. C. G. Williams. Effects of piston-ring width and radiusing edges of piston rings; comparative wear with cast-iron and aluminum pistons; effects of foreign matter on oil and oil viscosity; formation of oil film on cylinder walls; and tests on chromium-plated cylinder bores and piston rings. Fourth Interim report of Institution of Automobile Engineers Research Committee. *Automobile Engineer*, August, 1938, pages 289–294, 18 illus., 12 tables.

Diesel Developments. A. Castellini. New method of atomization by compressed air at normal temperatures has brought the fractionation of the liquid to a high degree and has made possible an intimate mixture with air. New apparatus referred to is fitted with an automatically controlled metering pump to control the mixture strength which regulates everything. Even if fuels of poorer calorific value are substituted there is no reduced power output. Advantages of the method in Diesel engines and application to gasoline engines are discussed but no details of the method itself are given. *Aeroplane*, September 14, 1938, pages 311–312.

Cooling Under Pressure. M. Victor. Junkers system for cooling engines uses a radiator under pressure which permits the boiling point of the water to be raised considerably. Much smaller radiators can be used. If pressure of the circulation of water is raised by 4 kg. the boiling point of the water is raised to 150°. Temperature difference between surrounding air and the liquid is doubled and the radiator surface can be reduced by half. The same results are obtained as with the use of ethyl glycol without encountering any of the difficulties likely to result from the use of that "corrosive, inflammable and very expensive product." Difficulties arising from the use of ethyl glycol are pointed out, a few details of the Junkers system are quoted, and its possibilities considered. *Les Ailes*, September 22, 1938, pages 7–8, 1 illus., 2 tables.

Strength of Articulated Connecting Rods in Aircraft Engines. H. Wiegand. Stress distribution in articulated connecting rods of radial aircraft engines was investigated in the tests described and the best designs for such rods are discussed. Question of the most suitable metals for connecting rods is also considered. Photographs illustrate various types of failures which occurred in the rods. *Luftwissen*, August, 1938, pages 289–292, 9 illus.

Tests to Explain the Detonation Process. A. Koechling. Tests discussed were carried out in the engine laboratory of the Technical College of Dresden with the purpose of gaining greater insight into the nature and cause of the detonation process. An essential part of the detonation process seems to be the detonation vibration which occurs. Influence of operating variables, such as excess air ratio, chemical constituents of fuels, initial pressure and temperature, as well as oxygen content of combustion air and rate of combustion, on the formation of detonation vibrations were investigated systematically. Results obtained so far indicate relations which do not readily fit into previous conceptions of detonation. *V.D.I.*, September 24, 1938, pages 1126–1134, 50 illus.

Fuels and Lubricants

Motor Fuel Economy of Europe. G. Egloff. Substitute motor fuels produced in Europe. Direct hydrogenation of coal; hydrogenation of carbon-monoxide from coal; benzene motor fuel; compressed gas; alcohol motor fuels; producer gas from wood, charcoal, anthracite; brown coal, lignite and lignite briquets; oil-shale motor fuels; ammonia, hydrogen and acetylene as motor fuels; ways in which 100-octane fuels are obtained from Europe's substitutes; import duties, taxes and prices of gasoline; and excess costs of substitute fuels over gasoline. *Industrial and Engineering Chemistry, Ind. Ed.*, October, 1938, pages 1091–1104, 16 illus., 13 tables.

Engine, Fuel, and Lubricant Testing

The Automobile Research Committee. Equipment of the research laboratory of the Institution of Automobile Engineers which is used for bearing-temperature research. New engines, improved Bryce high-speed electric dynamometer, location of thermocouples, special oil-feed pumps, and control equipment for the oil inlet temperatures and pressures are described. *Automobile Engineer*, September, 1938, pages 335–336, 1 illus.

Test Engine for Determining the Detonation Tendency of Fuels. W. Wilke. Test engine developed by I. G. Farbenindustrie and recognized by the German Ministry of Transportation as the German test engine for Otto-cycle-engine fuels. Development and construction of the engine are described and test results given. Experiences of the I. G. Farbenindustrie in the development and investigation of a test engine for Diesel fuels are discussed in detail. It is hoped that this engine will serve as a basis for standardizing test methods and test engines for Diesel fuels. Reference is made to the D.V.L. method of measuring ignition delay. *V.D.I.*, September 24, 1938, pages 1135–1142, 35 illus., 1 table.

Testing Coolers and Heaters. Gallay wind-tunnel for testing radiators and heaters has a large blower giving a maximum wind speed of 150 m.p.h. For very accurate work such as heat-transference tests for new radiator blocks or oil coolers, or pressure-drop tests through radiator elements, the suction end of the tunnel is used where airflow is smoother. Hot-water circulation used in conjunction with the heat-transference test is capable of producing 8000 b.t.u./min. Maximum flow, automatically maintained constant, is 50 gal./min. Similar system for oil coolers circulates 800 gal./hr. and produces 1800 b.t.u./min. Description. *Flight*, August 18, 1938, pages 157–158, 2 illus.

Engines

The Civil-Rated Bristol Perseus. The Bristol Perseus XII C sleeve-valve engine recently completed an endurance test lasting 260 hr., each 10-hr. period including 10 min. under maximum take-off conditions (900 hp. at 2700 r.p.m.). Most of the running was performed under conditions of extreme fuel economy. Final 10-hr. period was devoted entirely to running under take-off conditions, and for 5 hr. the engine was delivering its maximum power. Few details of endurance test and engine, with reference to the new internal oil seal in the propeller shaft and reduction gear assembly.

The strengthened Empire flying boats and the new Burnelli-type Cunliffe-Owen transport are among the new civil aircraft to be fitted with the new Perseus sleeve-valve engine. *Flight*, October 20, 1938, pages 332–334, 5 illus.

Bristol Perseus XII Aircraft Engine. Moderately-supercharged 9-cylinder sleeve-valve radial aircraft engine, now being put into quantity production, develops a maximum of 905 hp. at 6500 ft., and take-off power of 830 hp. International rating is 715–745 hp. at 6500 ft. Bore and stroke $5^3/_4 \times 6^1/_8$ in., cubic capacity 24.9 liters. Description. *Automobile Engineer*, July, 1938, pages 263–264, 3 illus.

The "Complex" Engine. F. Baudot has calculated and designed a new engine derived from the prototype and arranged as a double flat twin each having 8 cylinders. The two identical engines grouped together should give 16 liters total cylinder capacity or, with 50 hp. per liter, around 800 hp. total output. Short reference to previous Baudot design which was given up, and to a prewar model. *Les Ailes*, September 22, 1938, page 8.

The Diesel in Service. Dr. Stuessel. Deutsche Luft Hansa's experience with Junkers heavy-oil engines. Fuel consumption of 0.375 lb. per b.hp.-hr. has been obtained in service under all conditions and without any kind of complicated regulating mechanism. Primary trouble with the Jumo 204 650-hp. engine was with the design of pistons, and in the Jumo 205 as well until effective protection from the high-combustion temperatures was obtained only by fitting a heat-resisting plate over the crown of the light-alloy piston. Other troubles are discussed. Table shows consumption-performance figures for the Do.18 and Ha.139 and drawings illustrate the construction of the Jumo piston and double-ended cylinder. Abstract from I.A.T.A. paper. *Flight*, July 14, 1938, pages 47–48, 4 illus., 1 table.

The Lowdown on Diesels. Although Luft Hansa has piled up a lot of hours on them (over 16,000 in 1937 alone) Junkers Diesel engines are not yet a paying proposition over gasoline engines on ordinary routes. Increased maintenance costs have more than soaked up the saving on fuel bills. They have a tough spot in the piston that closes up the exhaust ports.

B.M.W. is testing a radial Diesel using a lot of parts from the Hornets built under license. It is a four-stroke, using the same induction system less carburetor and same valve action. Fuel pump is put back on the accessory section and nozzles are put in the cylinder heads.

A prestone-cooled model is being made that also interchanges with the gasoline engine. Cylinders are jacketed and six small radiators are placed around between them. Output is about 650 hp. for take-off and 500 hp. continuous. Fuel consumption is around 0.37 lb./hp.-hr. Two-row engines around 1000 hp. will be the next step. Brief references. *Aviation*, October, 1938, page 63.

New Aircooled Two-Row Aircraft Engines. Argus As 401 8-cylinder inverted-vee engine (90° cylinder angle) has been developed from the As.10 and has an elastically-driven centrifugal supercharger. Take-off output 275 hp. at 2100 r.p.m. Output for 5 min. 270 hp. at 2050 r.p.m. at 3 km. Continuous output 220 hp. at 1900 r.p.m. at 3.5 km. Weight 0.86 kg./hp. Fuel consumption 210 g./hp.-hr.

Hirth HM.508 is an 8-cylinder inverted-vee engines (60° cylinder angle) developing 240 hp. for 5 min. and 200 hp. for cruising. The 508D develops 280 hp. for 5 min. and 225 hp. for cruising. Fuel consumption is 214 g./hp.-hr. and weight 0.75 kg./hp. Description, characteristics and performance of all three engines. *Luftwissen*, August, 1938, pages 295–296 5 illus., 2 tables.

The Latest. New performance data on the following aircraft engines: *Bristol Aquila IV* sleeve-valve unit (cubic capacity 950 cu. in., diameter 46 in., take-off maximum 600 hp. at 3000 r.p.m., maximum level flight 540 hp. at 6000 ft. at 3000 r.p.m.). Two-speed supercharged *Pegasus XVII* and *XVIII* engines (take-off power 965 hp., maximum power for all-out level flight in "M" gear 1000 hp. at 3000 ft.). *Alvis Leonides* radial engine (maximum power 440 hp., take-off power 450 hp.) which operates on 87-octane fuel and weighs 680 lb. Other details are given. *Flight*, October 20, 1938, page 334.

A New Type of Rotary Motor. Twenty Sklenár rotary aircraft engines have been ordered by the French Air Ministry. Crankshaft turns at up at 4000 r.p.m., and the cylinders turn also but at one-ninth crankshaft speed.

Cylinder barrels rotate inside a fixed crown in which are inlet and exhaust ports and spark plugs. They are charged as they pass the inlet port, fired as they pass the spark plugs and are exhausted as they go by the exhaust port. Sealing between the ends of the barrel is described. Reference is made to another engine of the same type (9 cylinders) to develop 350 hp. which is being tried out, and to a double-row 700-hp. engine which is being designed. Two Mawen companies have been formed to build engines, one in France and the other in the United States. Short description. *Aeroplane*, October 19, 1938, page 475, 3 illus.

Petrol-Injection Engines in Service. Junkers gasoline-injection pump has 12 cylinders arranged in two blocks suspended in the form of an inverted vee, each block comprising six piston pumps with fully automatic control. Junkers gasoline-injection engines have set up an excellent service record in the German Air Force. Difference between the Jumo 211-Ba and 211-Da is one of reduction-gear ratio. Each has a two-speed supercharger with automatic boost-pressure control. Take-off power has been increased 10 per cent over that of the carburetor engine. Capacity 2136 cu. in. Take-off 1100 hp. at 2400 r.p.m. Maximum 1050 hp. at 2300 r.p.m. at 4921 ft. Maximum 975 hp. at 15,584 ft. Short description, performance, advantages of gasoline injection, and deficiencies from the use of carburetors. *Aeroplane*, October, 19, 1938, pages 473–474, 2 illus.

PARTS AND ACCESSORIES

Carburetor by Chandler Groves. Carburetor described reduces ice hazard and provides automatic mixture compensation. It has been in use in the Navy and is now released for export. Two of the four walls of the rectangular venturi form the adjustable valve which regulates flow of air through the carburetor. Chamber with two diaphragms in the side walls is used to control fuel flow which is cut off when pressure on the diaphragm reaches a certain point.

A second article describes the Wright two-speed supercharger designed in cooperation with Air Corps engineers, and providing two degrees of supercharging, one for full power sea-level take-off and the second for higher altitudes. *Aviation*, October, 1938, pages 38 and 39, 4 illus.

Cooling Developments. In the French Rabalet design of a cooling installation to reduce cooling drag, the combined oil and coolant radiator is placed directly behind a vee inline engine in the form of a bulkhead. Cooling air is taken in at four flush openings placed immediately behind the propeller spinner and is led to the radiators through four curving venturi-shaped ducts. Difficulties of applying the system to the British Merlin or Kestrel engine are discussed.

Mercier radial engine cowling incorporating a smaller intake opening and slotted forward air outlet has been put on French aircraft. Reference to this cooling system and short description of the N.A.C.A. nose-slotted cowling tested on a Curtiss BFC-1 airplane. Reference is made to cooling systems of the Whitley IV, Henley, Battle, Hurricane and Spitfire, and illustrations are given. *Flight*, July 21, 1938, pages 62a–62b, 8 illus.

Aerial Photography

Oblique Photographs and the Photoalidade. R. M. Wilson. New photoalidade used in mapping from oblique aerial photographs, and principles upon which it operates. Mathematical analysis given is applicable generally to oblique photographs. *Photogrammetric Engg.*, April-May-June, 1938, pages 35–74, 7 illus., 10 equations.

Practical Considerations in Mapping from Oblique Air Photographs by Non-Stereoscopic Methods. O. M. Miller. Accuracy and speed of mapping from high obliques by nonstereoscopic methods, and references to the American Geographical Society's experimental survey of Northern-most Labrador from high oblique photographs. Quick-reading photogoniometer for measuring horizontal and vertical angles, and a monocular plotting instrument incorporating the pinhole mirror optical device invented by the author were used at the Society. Plotting of flat surface features, intersection of points, resection of air stations, extension of control, density of air stations and control, and estimation of speed and efficiency of mapping from high oblique photographs are discussed. *Photogrammetric Engg.*, April-May-June, 1938, pages 75–86, 3 illus., 4 tables.

Specifications for Topographic Mapping. G. D. Whitmore. Desirable specifications for accuracy in planimetric and topographic mapping, and special references to Tennessee Valley experiences. Need for standard mapping specifications and different opinions expressed; determination of practical accuracy specifications; selection of contour intervals; actual contract specifications; and status of test work to date. *Photogrammetric Engg.*, April-May-June, 1938, pages 87–93.

Time Intervals for Aerial Photography. T. J. Mitchell and C. L. Morrison. Set of curves showing the 1938 time intervals for aerial photography with minimum sun altitude of 30° under various conditions. Curves were computed by the hour-angle formula derived from the cosine law of spherical trigonometry, the hour angles for each even degree of declination being computed for a band of latitudes covering the entire United States. *Photogrammetric Engg.*, April-May-June, 1938, page 103–105, 3 illus.

Topographic Mapping with the Multiplex Aeroprojector. T. P. Pendleton. Stereophotogrammetric survey is being carried out by the Geological Survey and the Tennessee Valley Authority with the use of the Multiplex Aeroprojector. Important danger points to be avoided in use of the latter are pointed out. Flight altitudes, effect of high winds, Multiplex slate-top tables, need of flexible metal mounted paper, and need of air conditioned space are discussed. Mapping routine followed with the Multiplex Aeroprojector is described including: determination of map accuracy and scale, camera characteristics, directions of flights, photographic overlaps, flight maps, and determination of flight attitude in the preliminary planning; control planning; supplemental control surveys; map sheet preparation; diapositive plate preparation; and the mapping operation. Completion survey and inking and lettering the map also taken up. *Photogrammetric Engg.*, April-May-June, 1938, pages 94–102.

Aircraft Radio

Aero Radio Digest. Lear portable self-contained ground station for aircraft radio communication and navigation. Radio Receptor SML combined airport traffic-control and localizer beacon. International Telephone & Telegraph Radio Navimeter permitting rapid calculation of a variety of difficult problems in radio navigation of aircraft, such as position finding with a single transmitting station located on either side of the course, with automatic correction for the quadrantal error of the direction-finder installation. Western Electric Adcock-type airport ground direction finder which covers the airline radio communications range (2800–7200 kcs.), permitting its use with the existing scheduled and itinerant aircraft communications frequencies. Descriptions. *Aero Digest*, October, 1938, pages 96, 99, 6 illus.

Aviation Radio. D. Finke. Finch radio facsimile transmission system to be tested from ground to airplane. Lear complete gasoline-powered 250-watt portable radio station for use in connection with aircraft. Short descriptions. *Aviation*, October, 1938, page 48, 1 illus.

More Automatic Homing. Use of the automatic pilot to relieve the human pilot during blind approaches has been tested by Capt. P. Bailey who has been using his Puss Moth for experimental work on ultra-short-wave beams at Croydon. Homing equipment is used to align the machine on its approach course, this course being set on the automatic pilot, and the latter then flies the machine along the approach line with little or no attention. Few details of this development and of the P.B. Deviator which was described in the February 24 issue of the magazine. *Flight*, August 25, 1938, page 166.

Radio in Australia. Ground radio facilities provided for aircraft in Australia, routes on which they are used, and the radio equipment for aircraft manufactured in Australia. Few details. *Aeroplane*, October 5, 1938, page 419.

Radio Direction Finding. W. Immler. Methods of solution developed since the introduction of radio direction finders are reviewed and are critically compared in regard to their utilization for long, medium and short distances. Use of corresponding map projections is taken up. Elliptical shape of the earth, equations of error of radio bearing, reductions as to time, homing flight, and antenna errors are considered in great detail. The Telefunken "Position-Correction Device" Type 2135N is referred to and illustrated. *Luftfahrtforschung*, August 20, 1938, pages 409–425, 40 illus., 15 equations.

Aeronautical Industry and Production

Aircraft Manufacturing. Statistical review of the aircraft industry, including production, exports, number of different types of airplanes produced, employment, wages, and other points. Profits on producing Army and Navy airplanes also discussed. *Aviation*, October, 1938, pages 35–37, 6 illus.

Company Activities. Activites of Abrams, Aeronca, Aircraft Associates, Boeing, Brewster, Consolidated, Fairchild, Hamilton Standard, Howard, Phillips, Piper, Rearwin, Ryan, Solar, and Taylorcraft companies. *Aero Digest*, October, 1938, pages 21–22.

To Jump the Better. Decrease in British exports of airplane, airships, balloons and parts during August is the first during the current year. Sums paid for the exports in August and the eight months ended with August are given for 1936, 37, and 38. Brief reference. *Aeroplane*, October 5, 1938, page 424.

Let's Talk Business. Activities at the Glenn L. Martin, Douglas, Stinson, Ryan, Menasco, A.C. Spark Plug, Austin, Rearwin, Lockheed, Brewster, North American Aviation, Aeromarine Instrument, Aircraft Accessories, and Phillips Aviation companies. *Aviation*, October, 1938, pages 57, 59–60.

Pilots

Can the Human Body Keep Pace with the Airplane? Lt. Col. D. A. Myers. Altitude sickness; problems arising from the effects of high speed on living tissue; "blacking out" or temporary unconsciousness of the pilot; "flier's belly"; exhaust gases and other products of conbustion in airplane engines and their effects on man; carbon monoxide effects; and physiological and psychological effects of cold. Reference is made to a centrifugal machine at Wright Field. *Photogrammetric Engg.*, April-May-June, 1938, pages 106–115.

Causes and Elimination of Human Sufferings Produced by Flights in an Airplane at High Altitude. Medécin Commandant A. Flamme. Experiences of a doctor in a series of flights, the last reaching from 9000 to 10,000 meters. *Rev. de l'Armée de l'Air*, August, 1938, pages 871–876.

Twenty Hours in a Low-Pressure Chamber Simulating Conditions at 10,000 Meters. J. Romeyer. As a result of an unusual experiment made by Dr. Richou and Commandant Antola it was found that remaining at that altitude requires the use of a pressure suit or pressure cabin since the inhaler is insufficient. *Les Ailes*, October 13, 1938, page 3.

Developing the Reflexes. R. Guay. A pilot should be completely adapted to his airplane and the movements which he must make to operate the different parts should be automatic. Methodical development of the reflexes should permit these results to be obtained very easily. Examples are given. *Les Ailes*, September 29, 1938, page 7.

Improving Efficiency in Training. S. K. Jopp. Methods of training pilots in Switzerland. *Aeroplane*, October 5, 1938, pages 404–405, 1 illus.

Purpose and Procedure in Scientific Training of Modern Airline Pilots. R. T. Freng. Modern flight training practices and their application in air transportation, with special references to methods of United Air Lines. *U.S. Air Services*, October, 1938, pages 19–21, 2 illus.

Special Flight-Surgeon Duties of Medical Officers in the Flight Groups. H. von Diringshofen. Supervision of the physical and mental welfare of members of a flight squadron is discussed. *Luftwehr*, August, 1938, pages 324–326.